MAY 1986

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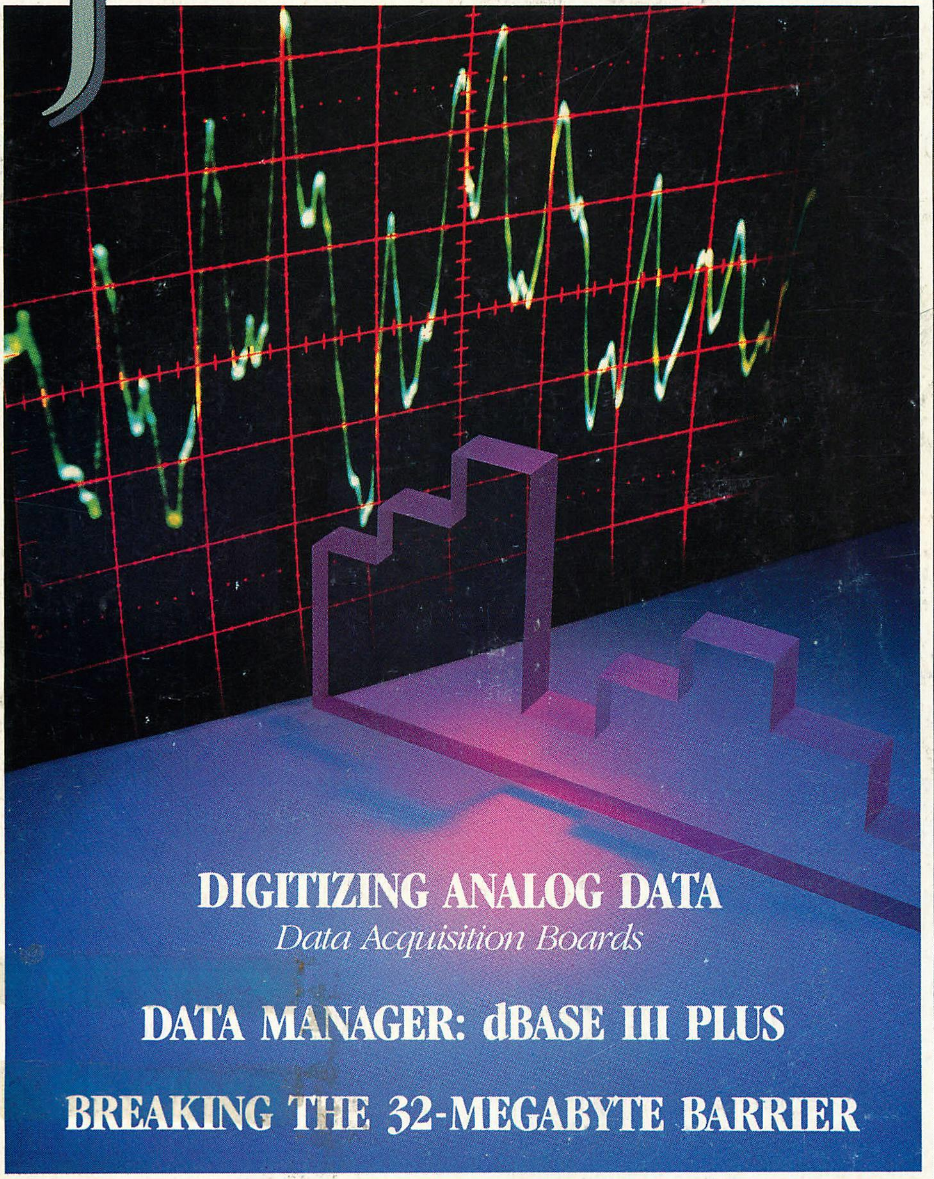
FOR IBM PERSONAL COMPUTER USERS

PC TECH JOURNAL



DIGITIZING ANALOG DATA
Data Acquisition Boards

DATA MANAGER: dBASE III PLUS

BREAKING THE 32-MEGABYTE BARRIER

Once upon a time
Tall Tree Systems introduced a 2MB memory board called JRAM-2. It broke the 640K and offered I/O modules, a warm re- data saver, and high speed BANK switching at an incredibly low $, and it worked like . Then one day a software company and a hardware company discovered the and issued an edict for a NEW! EMS. In no time at all **Tall Tree Systems** introduced JRAM-3 which used the NEW! EMS. It still has the , the warm re- , the BANK switching and the low $, but now it can multi-user and multi-tasking programs. Best of all it has a new called JLASER. It lets your HP Laserjet™ or other laser printer based on the Canon™ TALL TREE EXPRESS do full page graphics and custom typesetting just like .
The End

	JRAM-3	Rampage™	AboveBoard™
JLASER	✓		
re-	✓		
	✓	✓	
	✓	✓	
$	269	495	395

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Tall Tree Systems
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ZIM 2.5 A DBMS REVOLUTION

Have you been looking for perfect data management that you can enjoy on your own terms? Then you've probably already heard of ZIM 2.4 — the most powerful database system available. Until now. Because ZIM 2.5 is here.

ZIM 2.5 is a fourth generation application development tool which makes it possible to expand the capabilities of your micro beyond what you've ever imagined. ZIM mirrors the complexities of the real world by letting you develop as many and as varied applications as you could possibly need.

"ZIM is...a successful migration of mainframe ideas and needs to a micro. (ZIM) proves not only that the job can be done but also that it can be done well. ZIM provides a reference against which current and future data bases can be judged." James Creane, Data Based Advisor/July 1985.

Speed
ZIM breaks the speed limit — between 3 and 50 times faster than industry leaders in sorting and joining files within the data-base. ZIM's internal architecture, and the implementation of its strategy analyzer and priority-driven buffering ability, ensure that data is processed in the most efficient manner possible.

Portability
ZIM is the only database management system with 100% application portability for single-user and multi-user configurations. ZIM is available under PC-DOS, Concurrent PC-DOS, UNIX, XENIX, and QNX. Never again will you be required to re-write your applications for different operating systems environments.

Power
ZIM's high-level language lets you build user commands which implement applications without the necessity and cost of additional programming tools. ZIM's forms facility and extensive report generator permit completely menu-driven applications. Completed compiled, applications use the Runtime System, leading to fast execution, preventing unauthorized access or modifications, and decreasing cost and memory requirements.

Flexibility
ZIM gives you unprecedented simplicity and flexibility. ZIM commands parallel simple English sentences, making it easy to learn and use. Other features include automatic updates of all indexes, multi-user support, and an extensive range of validation, editing and masking facilities. ZIM's limits are only those of your hardware, operating system and imagination. And with ZIM 2.5, your database is no longer limited to a single hard disk.

"ZIM is (a) well-conceived, soundly-implemented, thoroughly professional system. Its design evidences a strong commitment to consistency and to the goal of natural nonprocedural user interaction."

Richard M. Foard, PC Tech Journal, October 1985.

ZIM 2.5 — DATA MANAGEMENT AT ITS BEST

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INFORMATION INC

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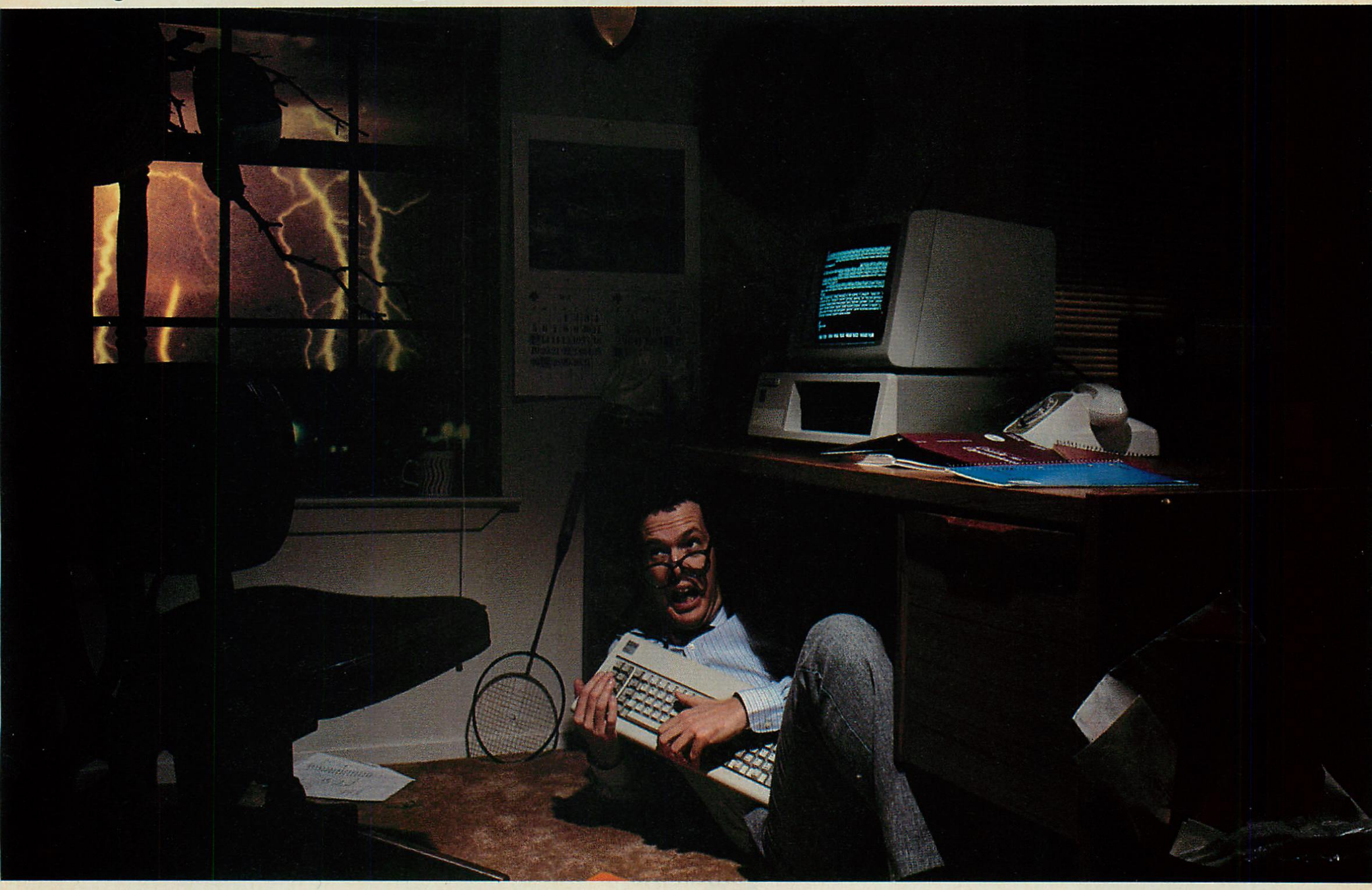
TOLL FREE

If lightning still scares you, you're using the wrong file manager.



Be sure. Btrieve.®

Lightning may strike. But it doesn't have to destroy your database.

Btrieve® file management offers automatic file recovery after a system crash. So accidents and power failures don't turn into database disasters. Your Btrieve-based applications will come up when the lights come back on.

Fast. Btrieve is lightning fast, too. Its b-tree file structure automatically balances—you never waste time reorganizing the index. And Btrieve is written in Assembly language especially for the IBM PC. The result: electrifying speed on file maintenance routines. Applications that run fast. Users who don't waste time waiting.

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Suggested retail prices: Btrieve, $245; Btrieve/N, $595; Xtrieve, $195; Xtrieve/N, $395; Rtrieve, $85; Rtrieve/N, $175. Requires PC-DOS or MS-DOS 1.X, 2.X, or 3.X.

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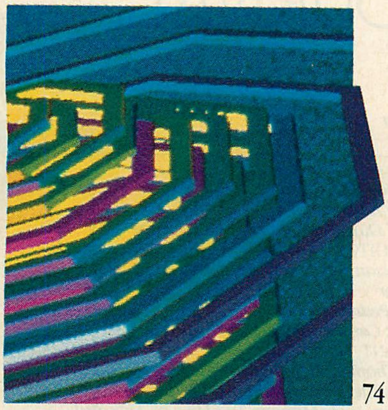
VOLUME 4, NUMBER 5



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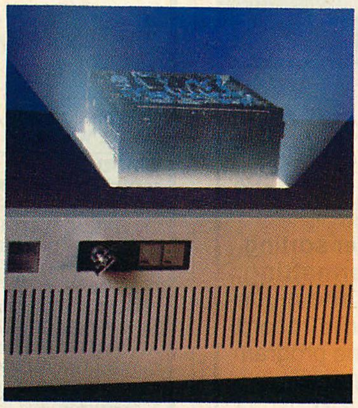

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Periscope Delivers Professional Debugging Power

Enhanced Graphics Adapter Support!

GET YOUR PROGRAMS WORKING FAST

"It works, and works well!! In the first day of use I finished up two weeks of problems!!" —Peter Loats

Periscope is "Always there with just a push of the button". Whenever something unexpected happens, just press the break-out switch and Presto! Periscope's debugging power is at your command. You can check out the problem right away.

Periscope uses names—symbols—from your program so you don't have to remember addresses. It displays source code and line numbers from high-level languages, too. You save hours of time because you access what you need with familiar names!

Periscope's unique breakpoints force bugs out from where they hide. With over 75 breakpoint options, including the ability to write your own breakpoint tests, you'll find those elusive bugs fast!

MAKE YOUR SOFTWARE RELIABLE

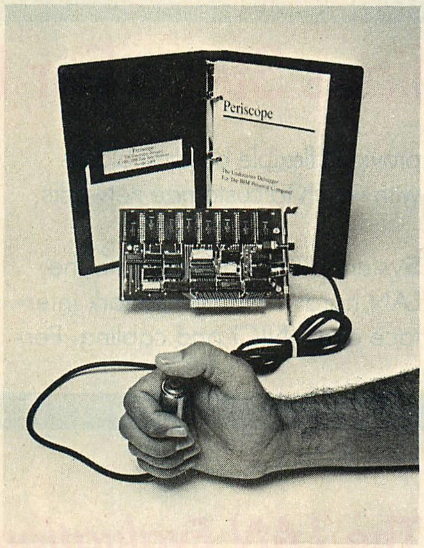
"I can't live without it!! BRIEF, a text editor my company wrote, would not be as stable as it is today without Periscope." —David Nanian

With Periscope's broad range of capabilities, you can thoroughly debug your software, giving it the reliability it needs.

One user says that Periscope is a "superbly engineered product" with "virtually every feature possible!"

Here's a sampling of the features:

- See procedure and variable names PLUS source code and line numbers from high-level languages!
- Symbolic In-line Assembler
- 75+ Breakpoint Options—including breakpoints on reads/writes to memory and I/O ports!
- Traceback—see up to 2,016 previous instructions!
- Optional Windows—change them while debugging!
- Optional On-line Help
- Single/Dual-Monitor Support — great for debugging screen-intensive programs!
- View Text Files
- User Exits—customize Periscope with your own programs!
- 8087/80287 Status
- Display memory in most any format



The break-out switch gives you what one user calls "spontaneity of debugging". Press it anytime to stop the executing program and see what's going on. The switch is so handy you'll want to use it to learn more about your PC!

DEBUG PROGRAMS OTHER DEBUGGERS CAN'T

"Periscope has changed my programming life and is truly unique among PC debuggers . . . [it] enables me to debug keyboard routines, device drivers . . . without errors. Periscope is rock solid." —Doug Roberts

Debug memory-resident and non-DOS programs, device-drivers, keyboard handlers, and interrupt-driven programs. Recover when your system hangs or your keyboard locks up. Safely check out what's going on in your system anytime. Debug when DOS is not working, debug DOS.

If your bugs can be found with a software debugger, Periscope can track them down! (We've heard that a competitor uses Periscope to debug his debugger.)

GET THE BEST VALUE!

"[Periscope is] the best value in development tools currently on the market." —Jeff Garbers

Time and again users tell us Periscope is underpriced. They tell us it pays for itself in a matter of hours after they begin using it. This means no professional software developer can afford NOT to try it!

Periscope I: Board, Switch, Software, Manual, Reference Card . . . . Just $295

Periscope II: Switch, Software, Manual, Reference Card . . . . Only $145

HOW TO DECIDE BETWEEN PERISCOPE I & PERISCOPE II

MEMORY BOARD

The key difference between Periscope I and Periscope II is the 'Submarine' board included with the Periscope I package. When you install Periscope I, crucial debugger software loads into the board's memory, which is then write-protected. You don't have to worry about a runaway program destroying it! Periscope II loads into low memory.

BREAK-OUT SWITCH

The break-out switch included with either model of Periscope enables you to debug anytime, even if your system is hung. The Periscope II switch taps into an already-in-use slot, so you don't need a spare slot to install it. The Periscope I switch plugs into the back of the 'Submarine' board, which requires a slot.

WHICH MODEL DO YOU NEED?

If your program writes to memory below itself, you need Periscope I's protected memory to make sure crucial debugger software isn't overwritten. Other than the protected memory, Periscope I and Periscope II are functionally the same debugger!

If you're not sure which model you need, call for details on our trade-up policy. You can buy Periscope II, then trade it in for Periscope I later if you decide you need the protected memory.

Periscope requires: An IBM PC, XT, AT or close compatible; DOS 2.0 or later; 128K RAM; one Disk Drive; and an 80-column Monitor

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Choosing a LAN System.

New Report Outlines Steps For LAN Evaluation.

Choosing the best local area network hardware for your particular installation is often a bewildering process. There are many options and few evaluation tools.

A new report developed by Novell, Inc., is designed to offer help. The study, *LAN Evaluation Report 1986*, examines all of the hardware issues that affect LAN performance. It includes an analysis of many LAN products and a series of benchmark tests.

A key element of the study is the addition of an evaluation system. The system provides a mechanism for matching site needs to specific hardware. Whether a new network is being planned or an existing site is being upgraded, the study will be useful in the performance evaluation of any proposed network. As a network operating system developer and system reseller, Novell has experience with LAN products from system support through installation and day-to-day operation. Novell's NetWare® network operating system supports 30 different LAN configurations including the NETBIOS-compatible LANs. Information in the *LAN Evaluation Report 1986* is based on that experience.

LAN Hardware Choices.

LANs are highly modularized architectures. The rich assortment of available LAN components provides flexible building blocks with which to customize networks.

System planning starts with the LAN hardware: the network interface card (NIC) and cabling. Personal computers and other machines are attached to a LAN by plugging the NIC into the PC expansion bus and attaching the LAN cable to the NIC.

"The *LAN Evaluation Report 1986* includes an analysis of many LAN products as well as a series of benchmark tests."

LAN hardware systems analyzed in the study are:

- AT&T StarLAN
- Corvus Omninet
- Davong MultiLink
- Gateway G-Net
- IBM PC Network
- Interactive Systems LAN/PC
- Nestar PLAN 2000
- Novell S-Net
- Proteon ProNET
- Standard Microsystems ARCNET
- 3Com EtherLink
- 3Com EtherLink Plus

The IBM Token Ring Network is also analyzed; however production NICs were not available at the time the report was written and could not be included in the benchmark tests.

The report analyzes each NIC according to its access scheme, raw bit rate, onboard processing, and NIC-to-host transfer method.

NICs divide information into message units called packets, transmit the packets at a certain speed, and manage the transmission and receipt of those packets. In other words, NICs implement a hardware protocol.

One of the points made in the analysis and benchmarks is that the way a protocol is implemented is often more significant to performance than the protocol itself. Many LAN vendors are actively modifying their NIC designs to improve performance without any change in the basic protocol.

Network Servers.

The network server manages all network requests and data storage functions. Because of this, the server plays a key role in LAN performance.

Servers come in many different configurations and designs. Some are proprietary boxes that were

specifically designed as servers. Others are personal computers that are functioning as servers.

The *LAN Evaluation Report 1986* analyzes and tests the following servers:

- IBM PC XT
- IBM PC AT
- Novell S-Net
- 3Com 3Server
- Novell 286A and 286B

Processor type is the most obvious difference among these machines. They use the Intel 8088, Intel 80186, Intel 80286 or Motorola MC68000. But other factors are also important in determining server performance, including processor clock cycle speed, wait states, server memory cycle speed, memory channel, and transfer bus channel. All of these factors determine the speed at which data is moved and processed.

One of the jobs that a server handles is sending data to and from the hard disk. The speed of the server cannot alter the speed of the disk channel. If a disk channel can handle reads at 160 kilobytes per second, a faster processor isn't going to change that figure.

A faster server, however, can change the percentage of processor utilization for specific servers. High-performance servers use less of the processor's time for specific operations, freeing the processor to perform other tasks. The result is increased performance.

NetWare Evaluation System.

The *LAN Evaluation Report 1986* contains the NetWare Evaluation System. While benchmark measurements are part of the system, they are designed to be used only as input in the evaluation formula.

The first of the two benchmarks is a measurement of maximum throughput for a LAN/server combination with a single workstation.

The second shows the maximum working bandwidth for a fully loaded network. In this test, six IBM PC AT workstations were attached to the various LAN/server combinations. The network was driven to its maximum traffic capability. Throughput results from all stations were totaled to show the maximum bandwidth of each network.

"The NetWare Evaluation System provides an excellent method of LAN performance comparison."

A formula for workstation usage is then developed based on specific values for a particular site. Five categories of network users are defined and used in establishing this site profile.

As a final step, the benchmark results and site profile are applied to a formula which shows the throughput of the proposed system.

Answers generated by the formula provide several useful pieces of information. The results from the formula should be approximately the same as the maximum throughput in a single station test.

If the working bandwidth of the proposed system is much greater than the single station throughput, this indicates that the LAN/server combination has more power than can be utilized by the proposed network. If the working bandwidth is much lower than the single station throughput, it indicates that the LAN/server combination will be overburdened.

The evaluation system also provides a method of performance comparison. Desired performance is usually expressed in terms of floppy or hard disk speed. The study contains data on the standalone workstation performance of the IBM PC AT and XT with both floppy and hard disks. Using these figures, the formula's results can be compared to desired throughput.

Read the Full Report.

The *LAN Evaluation Report 1986* is available free of charge from Novell. To obtain a copy, call or write Novell Corporate Communications, 748 North 1340 West, Orem, Utah 84057, (801) 226-8202.

NOVELL

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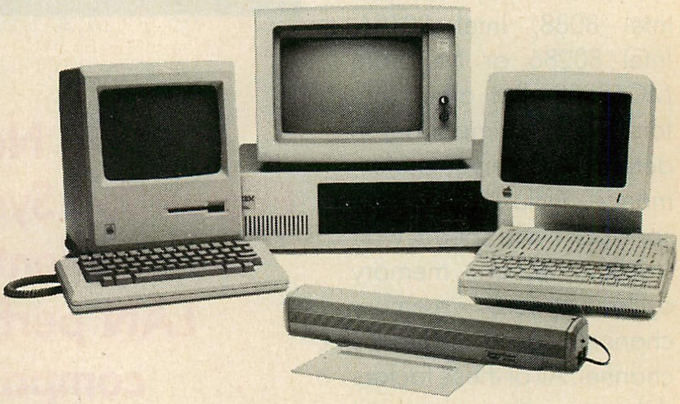
It's a question more and more PC owners are asking. And no wonder. What everyone is talking about is Softstrip™. The revolutionary technology that is changing the shape of computer software.

The Cauzin Softstrip System is more than just software or data on paper. Because when you invest in this system, you can do much more with your computer, and for far less than you are probably spending now. You can even create and print out your own data strips using a dot matrix printer and a special StripWare™ program called "STRIPPER" that's only $19.95.

But that's only the beginning of an offer that's going to make you wonder why you haven't stripped yet . . .



TAKE OUR ADS (SUCH AS THIS ONE)

It's part of our expanding StripWare™ Library containing programs, data, art, spreadsheet, macros and templates. The Library features a variety of software applications and you'll find new material appearing each month in such leading computer magazines.

When you invest in the Softstrip System, you get the Softstrip reader, a special storage base, and a full one-year replacement warranty. Also included with your purchase is a complete Accessory Kit for your PC containing connector cables and communications software to link your computer to the reader.

In addition, you'll find a StripWare Sampler with 48 programs from a line-up of popular authors and publishers that includes Addison-Wesley, David Ahl, Family Computing, Tim Hartnell, Hayden Books, PC Tech Journal, Osborne/McGraw-Hill, The Waite Group, and John Wiley & Sons.

When you become a Softstrip reader owner, you also get a FREE one year StripWare Club membership with programs mailed to you monthly. You'll even receive a FREE Cauzin Effect Newsletter filled with the latest updates and news about Softstrip developments.

The Cauzin Softstrip System is just that, a complete system that opens up a new world of computer programs and data on paper. And it's all yours for only $199.95!

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Waterbury, CT 06706

FILLING UP ON REGULAR

The data strips on the right contain the REGULAR program, by Jon Forrest, which appears in the Programming Practices section (pp. 194) of this issue. REGULAR.COM is a text searching program that works just like the FIND.COM program supplied with your DOS.

So why do you need another program? There's one big difference between the two: REGULAR's search string is a Regular Expression, not a DOS wildcard. Extremely powerful, the Regular Expression syntax is often used when writing compilers.

Programmers will find this program to be remarkably useful. Search strings can be either highly detailed or extremely vague searches. Use it to search for syntax, items in parentheses, or all the words starting with capital "A" and ending with e.

After you read in the data strips, refer to the article on page 191 for more details and complete operating instructions.

StripWare Library No. 259

5 6 7 8

Softstrip

ATRON BUGBUSTERS GREASE BORLAND LIGHTNING

"If I were starting a software company again, from scratch, Atron's AT PROBE™ would be among my very first investments. Without Atron's hardware-assisted, software debugging technology, the flash of Turbo Lightning™ would be a light-year away."

Philippe Kahn, President, Borland

HOW BORLAND DOES SO MUCH, SO WELL, SO FAST

We asked Borland International president Philippe Kahn to share his secrets for rapidly taking a good idea and turning it into rock-solid reality. How does the Borland team do so much, so well, so fast?

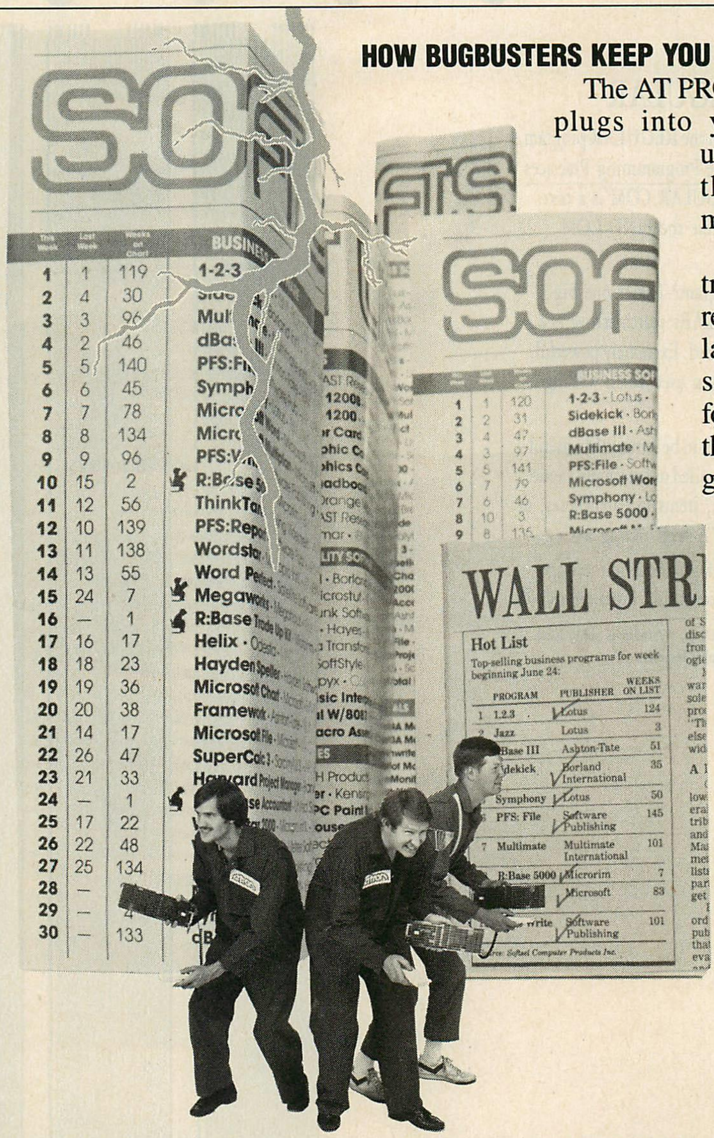
He begins, "I remember when Atron used the June 24, 1985 *Wall Street Journal* chart of top-selling software in an ad." [Note: At that time, seven of the top ten software packages were created by Atron customers; it's now now nine out of ten.] "Side-Kick was number four, and I let Atron quote me in saying that there wouldn't have been a SideKick without Atron's hardware-assisted debuggers.

"You might say lightning has literally struck again. Turbo Lightning made number four on *SoftSel's Hotlist* within weeks of its introduction! And again, I say we couldn't have done it without Atron debugging technology.

"Cleverly written code is, by definition tight, recursive, and terribly complex," he continues. "Without the ability to externally track the execution of this code, competent debugging becomes very nearly impossible."

Concludes Philippe, "And after Turbo Lightning was solid and reliable, Atron tuning software turned our Probes into performance analyzers. How do you think we *greased* our lightning?"

Philippe, along with a couple million or so of your satisfied customers, we say congratulations on yet another best-selling product. We can't wait to see what awesomely useful technology will come shooting out of Borland International next.



HOW BUGBUSTERS KEEP YOU FROM GETTING SLIMED

The AT PROBE is a circuit board that plugs into your PC/AT. It has an umbilical which plugs into the 80287 socket and monitors all 80286 activity.

Since AT PROBE can trace program execution in real time, and display the last 2048 memory cycles in symbolic or source-code form, you can easily answer the questions: "How did I get here?" and "What *are* those silly interrupts doing?"

It can solve *spooky* debugging problems. Like finding where your program overwrites memory or I/O - impossible with software debuggers.

You can even do source-level debugging in your favorite language, like C, Pascal or assembler. And after your application is debugged, the AT PROBE's performance measurement software can isolate performance bottlenecks.

Finally, the AT PROBE has its own 1-MByte of memory. Hidden and write-protected. How else could you develop that really large program, where the symbol table would otherwise take up most of memory.

LOOK AT IT THIS WAY.

History shows that non-Atron customers don't stand a very good chance of making the Top Ten list. Lightning *really does* have a way of striking twice!

The PC PROBE™ is $1595 and the AT PROBE is $2495. So call Atron today. You can be busting some really scarey bugs tomorrow. And maybe, just like Borland, you can also bust some records.

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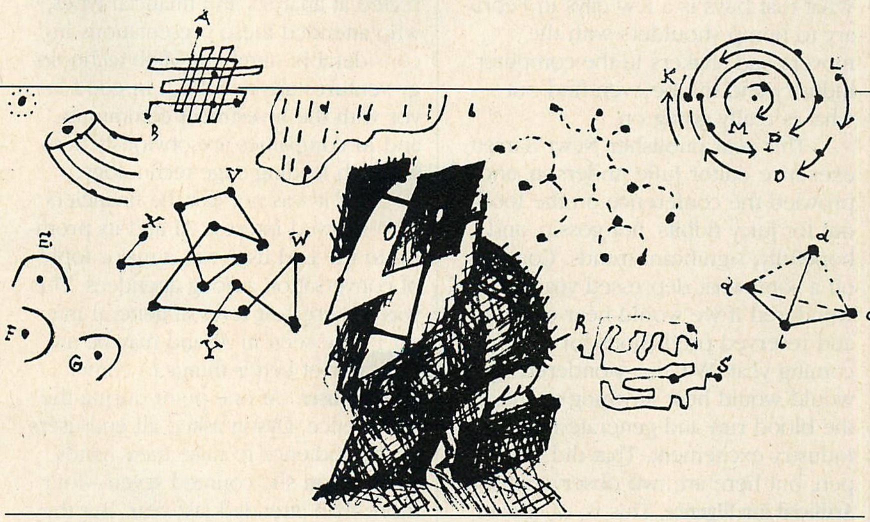

ILLUSTRATION • MACIEK ALBRECHT

Recently, I've been programming. Yes, I admit it. Every once in a while, I set mechanical pencil to paper and keyboard to screen to build something. Notwithstanding previous comments about not *wanting* to program ("Database Programs are Complex," Directions, February 1984, p. 11), sometimes a program is the only solution.

My efforts of late have been varied. First I wrote about 1,000 lines of PAL (Paradox Applications Language) for last month's data manager review. Then I added 400 lines of Turbo Pascal to enhance a 500-line program *PC Tech Journal* uses to prepare the camera-ready copy of our listings on a laser printer. Next was the conversion of a 20-module C program (a game I once wrote) to the Microsoft C compiler as a test of C's portability and to try some new debugging tools. I then slid back over to Turbo to modify a source file lister to produce reasonable hard copy of the game program.

In the meantime, I am immersed in other languages. Reviews of BASIC interpreters and compilers are in progress. A review of Prolog implementations was published in January ("Programming in Logic, Michael Covington, p. 145). Microsoft has released new versions of just about everything, and we had to explore inter-language calling methodology, new debuggers, and COBOL tools. LISP and TI's SCHEME have a heavy presence in the office at the moment. And last, but not least, I have been poring over *PC Tech Journal's* recent research to see what our readers are doing with languages.

So I am up to my armpits in C and Pascal and MASM and LINK and MAKE and SYMDEB and Periscope's breakout button and David Schwaderer's great *C Wizard's Programming Reference*; I am longing for a 20-MHz AT with a 50MB, 5-ms disk, and I am taxing my family's patience and my own longevity by adding just one more function or fixing just one more bug at 2 a.m., all the while swilling Coke (Classic) and munching M&M's and aurally inputting dangerous levels of rock 'n roll.

This is exactly what I was doing when I became a professional programmer in 1973. I am a bit more efficient now, and I know how to avoid many, many pitfalls, but the basic (no pun) work is unchanged. Code, edit, compile, link (except for Turbo), debug, and do it again—with tools that are fundamentally the same as 13 years ago. Sure, they are on a micro; some of them are inexpensive, and some are pretty neat. But *I* still have to balance BEGIN-ENDs or parentheses. *I* still have to observe tight syntax rules. *I* still have to develop strategies and algorithms for even the simplest of tasks. Most important, *I* still have to reduce the abstract problem to a set of instructions that, when complete, do not themselves bear much relationship to the original problem.

We have arrived at a point when the tree of research in artificial intelligence may finally bear fruit for the end user. A number of packages now on the market, such as MDBS's Guru and TI's Personal Consultant, are tools for building expert systems. Mass market interest in AI is growing and is bound to be spurred on by the availability of under-$100 products such as Turbo-Prolog and TI SCHEME; SCHEME, in particular, may increase the understanding of LISP as a prototyping language.

So what do I want? I was struck by a remark made by Peter Gabel of Arity at the Personal Computer Forum in February (see sidebar on next page): Arity Prolog is built as an open system so that Prolog programs can be directly integrated with C, FORTRAN, Pascal, COBOL, or whatever. There are many places in programs where I would much rather state the rules than write procedural code. Why not let a program reason and infer at certain points and sequentially process at others? If I could do that, certain difficult sections of code could be handled in terms closer to the problem than the machine and with far less time and work on my part.

But then, I thought, why program in the traditional way at all? Why couldn't an expert programming assistant turn my rules and descriptions into programs? Why couldn't it keep track of all the pieces and use them as needed? Why couldn't it modify my previous code to meet new requirements, asking only for the new constraints?

This is not a pipe dream. Technological barriers may stand in the way, but even now we can surely do better than the software engineering technology of 15 years ago.

A SOIREE IN PHOENIX

It's tough in the trenches.

First, you subscribe to Esther Dyson's RELease 1.0. Then you pony up $1,000 (okay, she is a marketer; the price is actually $995) to enroll in her now-famous, annual industry forum in Phoenix. Then you ante up another $1,000 or so to stay at exclusive Pointe Tapitio, high above scenic Phoenix. What that buys is a few days in February to bump shoulders with the movers and shakers in the computer industry and maybe even find out what is really going on.

This year publisher Newt Barrett, executive editor Julie Anderson, and I prowled the conference on the lookout for juicy tidbits, hot gossip, and, hopefully, significant trends. Coming off a somewhat depressed year, we wondered if we would hear caution and reserved predictions for the forthcoming year. We also wondered if we would hear anything to make the blood run and generate renewed industry excitement. That did not happen, but here are two observations.

Artificial intelligence. This is, of course, one of Dyson's pet areas, so it was no surprise to see so many AI companies represented at the forum and in the unique company sessions that fill each afternoon. A greatly increased acceptance of and interest in AI technology was quite evident. The AI company sessions I attended each began with a description of the firm and its finances; such information is clearly directed at analysts and financial types, who attended these presentations in considerable numbers. High-technology ventures are now back in good favor with the investment community, and AI companies are obviously dealing with leading-edge technology.

But it was not just the financiers who showed interest. AI and its promise to the end user was a major topic of conversation among attendees. This was the greatest level of general interest I have seen in AI and may be an indicator of better things to come.

The end user. At one point during the conference, Dyson asked all end users in the audience to raise their hands, whereupon she counted seven—four more than attended last year. But they were feisty and found themselves well-represented on several panels by Danielle Barr, a vice president with the Bank of New England.

They also found themselves in the driver's seat. If no other theme pervaded the conference, the importance of end users and the need to deliver functionality to them certainly did. That may sound strange: how could we be in business if we did not focus on what the user needed?

The growing realization is that we have for too long focused on what we *thought* end users needed. They got us into business to begin with by buying so many of the computers that this industry built; now they are asking us to pay attention to what they really need, what will do them the most good. They want us to pay attention to standards and make their investment pay off for as long as possible.

So no revolution emerges from Phoenix. But some signs indicate that the desktop computer industry is evolving from infancy to childhood, that we are learning to walk and talk.

That's a good sign in itself.

—*WF*

A BASH IN SEATTLE

The "First International Conference on CD ROM" was held in Seattle during March, sponsored and elegantly hosted by Microsoft.

CD ROM, which stands for compact disk/read only memory, is the second stage in the evolution of optical, read-only media—the first stage being the audio compact disk. It is a plastic disk, about 19 mm (4¾ inches) in diameter and 2 mm thick. It can hold about 500MB of data—about 250,000 pages of single-spaced text. Assuming that the data are properly formatted, a CD ROM can be mastered for as little as $3,000 and produced for as little as $20 per disk in small quantities.

The ability to put such vast quantities of data on such a tiny and inexpensive media has spawned an industry. Perhaps most visible is Gary Kildall's company, KnowledgeSet (formerly Activenture), which, with Grolier, has produced a text-only encyclopedia on CD ROM and built a product called KRS (Knowledge Retrieval System) to access it from desktop computers. This emerging business hopes to put just about any kind of data imaginable onto CD ROM.

Two examples stem from Microsoft's commitment to the technology (it has formed a separate division to concentrate on CD ROM). The first is an impressive multimedia demonstration disk that includes text, still pictures, audio, and video. The demo shows how reading an article about the Olympics could be enhanced by photos of key events or how the subject of DNA could be driven home by a rotating model of the double helix.

The second example is *The New Papyrus*, a 600-page collection of papers published by Microsoft Press just in time for the conference. Computer Access Corporation worked with Microsoft Press to take the data files that were used to prepare the book, invert them (build a complete, word-by-word index), and plop them onto a CD ROM, a project that was completed in just three weeks. Computer Access's program Bluefish, a full-text data management system, provides the engine needed to locate word references anywhere in the book.

A standard for the CD ROM media already has been fixed. This means that any CD ROM reader will read any CD ROM. However, several different hardware interfaces remain, even to the IBM PC, as do many different software access methods. It takes Bluefish to read *The New Papyrus*, KRS to read Grolier, and Windows and special Microsoft drivers to read Microsoft's fancy demo; in each case, the software must be equipped with drivers to handle the hardware.

Worse, the mini-industry seems poised to launch CD ROM just as the giant Philips/Sony consortium announces the CD-I (for interactive) specification, the final evolutionary step and one that is as important as it is confusing.

Such is the promise of CD ROM that 800 people paid to learn about it—500 more than Microsoft projected and 200 less than wanted to attend. What Microsoft's conference demonstrated was a dazzling technology, rampant interest, and much more serious work to come.

—*WF*

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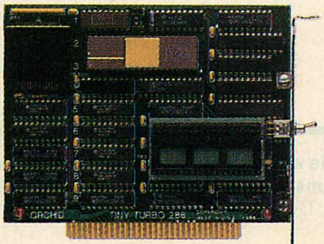

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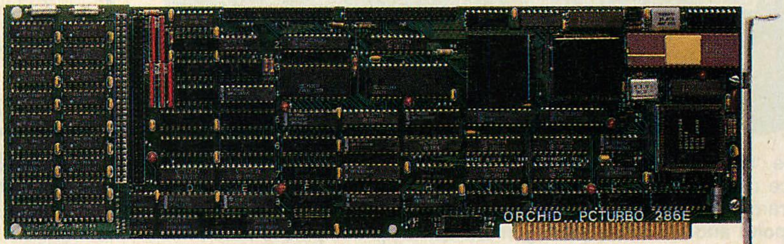

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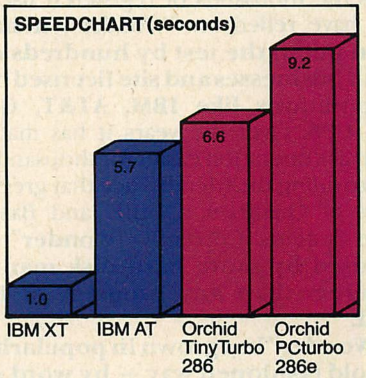

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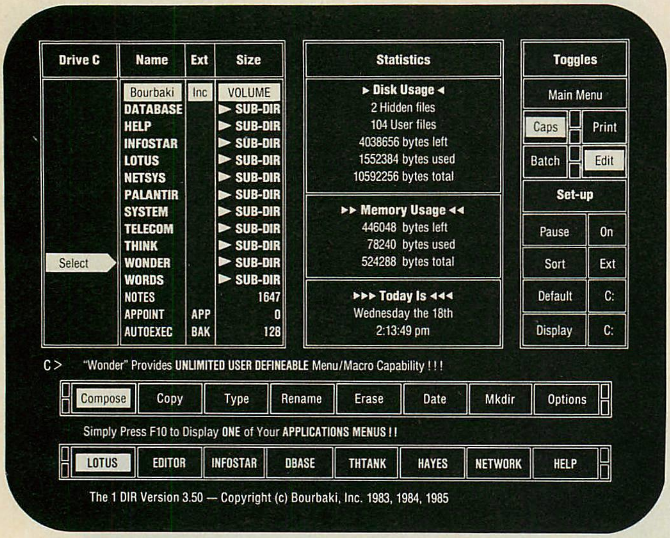
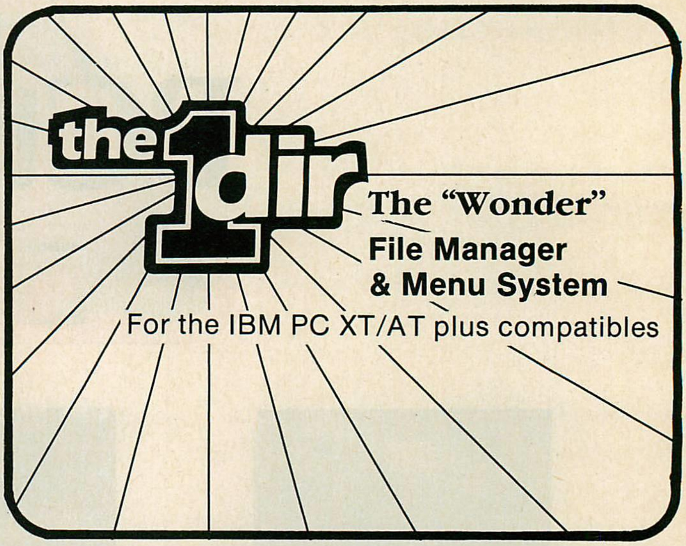


The "Wonder" screen acts as a sophisticated control panel to guide novice users and speed experienced users through the intricacies of program selection and file management. **Its menuing/macro functions and point and shoot file management can help companies as well as individuals Organize, Customize and Standardize computer operations.**



"Wonder" is compatible with IBM, its compatibles, portables and a wide range of network systems. System requirements — IBM PC/XT/3270 PC/AT/jr. or compatible; DOS 2.0 or higher; one disk drive.

3. It's PROVEN

"Wonder" has earned high marks and a reputation as an industry standard through years, not months, of user input and development. Besides the thousands of registered users that have relied on "Wonder", **it has been put to the test by hundreds of small businesses and site licensed by corporations like IBM, AT&T, GM and UPS.** Over the years it has made hard disk operation easier for thousands, by providing the friendly face that greets users of Quadram, QUBIE' and Basic Time Systems. Currently **"Wonder" is licensed by more hard disk manufacturers than any program of its kind.**

"Wonder" has grown in popularity the old fashioned way — by word of mouth from one satisfied user to the next. Today those words are echoed by those who review the industry — here's what they're saying.

Compute 10/85: *"Whether you're a beginner or an experienced user,* **1dir** ("Wonder") *can simplify your introduction to MS-DOS and make your time on the computer more productive."*

Info World 11/85: *"This is the one we would choose if we really needed the powerful features . . ."*

PC Products 8/85: *"Quite simply* **1dir** ("Wonder") *works flawlessly . . ."*

PC 12/85: *"Overall* **1dir** *does indeed spell* WONDER."

2. It's POWERFUL

"Wonder" is not only an uncomplicated environment for beginners, it's also a sophisticated tool for experienced users. It's excellent in a hard disk environment where file organization and accessibility are a must. The "point and shoot" "Wonder" system makes single or multiple file operations fast and nearly effortless.

With the unique Menu Builder **you can create single key stroke commands to run programs or perform any multi-file, multi-command operation.** The utility of the Menuing System is that it functions with the same simple cursor movement that drives the rest of "Wonder", so any user familiar with File Management can easily build custom menu commands. **Almost anyone can create a turnkey system that takes the hassle out of DOS forever.**

Many corporations have an ulterior motive for introducing new users to "Wonder". Its menuing system is an excellent vehicle for establishing standardization. Through a system of shared commands **companies can assure speed and uniformity while reducing support requirements.**

Don't settle for JUST file management. Get the extended power of "Wonder".

1. It's EASY

Many corporate training centers and independent training consultants across the country use "Wonder" to soothe initial fears and pave the way to increased productivity. **It eliminates the complex and hidden nature of DOS and replaces it with a point and shoot file management system.** With "Wonder," training centers are finding that beginners don't stay novices for very long — the average is DOS literate and functional in hours not days.

The same strengths that make "Wonder" popular with training specialists make it ideal for independent users. First **"Wonder" requires no special training; all major functions are cursor driven.** It eliminates the need for you to remember syntax or type DOS commands. Secondly **"Wonder" includes a DOS help system that can actually help beginners to learn DOS basics.** And, finally, "Wonder" is easy to install — **a relative novice can install a basic system in minutes.**

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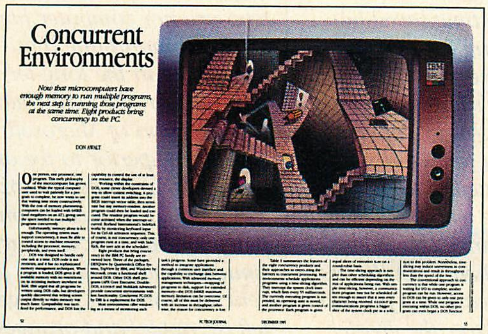

THE CASE FOR CONCURRENCY

The December 1985 issue of *PC Tech Journal* included an article entitled "Concurrent Environments" (Don Awalt, p. 52) and an accompanying table that compared various concurrent operating systems for the PC/XT and PC/AT. Unfortunately, several factual errors were made concerning Concurrent PC-DOS.

First, Concurrent PC-DOS allows the user to run up to four PC-DOS tasks and an unlimited number of CP/M tasks. Second, code and data sharing is supported on .CMD programs. Third, the user can cut and paste between applications by using the Window Manager of Concurrent PC-DOS; the on-line help system outlines this function. Fourth, developer kits are available for all of our operating systems, including Concurrent PC-DOS. Finally, Concurrent PC-DOS extended memory will be supported as of an April release.

In conclusion, Concurrent PC-DOS from Digital Research *is* a true concurrent operating system.

Michael Loftus
Manager, Systems Software
Digital Research, Inc.

CP/M features of Concurrent PC-DOS (C/PC-DOS) were not reviewed, only its MS-DOS software. For more detail, the reader was directed to a previous review of the product. The number of concurrent CP/M tasks that can execute the code/data sharing of .CMD programs only (not MS-DOS .EXE or .COM files) therefore were not mentioned. I might add that the 640KB memory restriction of C/PC-DOS 4.1 makes statements about running an "unlimited number" of tasks impractical.

Cut-and-paste is available through the COPYMENU command. It was missed because the manual makes no mention of it; it is only referenced in the on-line help.

Digital Research includes an order form for a C/PC-DOS Programmer's Guide, which provides technical information on system calls and operating system characteristics of C/PC-DOS.

—Don Awalt

In the December 1985 issue, Don Awalt's "Concurrent Environments" was timely and informative. However, I disagree with a few of his assertions.

Because many programs do not issue system calls continuously, time slicing is usually more efficient than nonpreemptive scheduling at balancing the performance of concurrent programs on the PC. (It certainly is less "simple" to implement than nonpreemptive scheduling, and my experience with Crosstalk XVI running under DESQview suggests that lost characters should not be a problem at 1200 baud with a buffered, interrupt-driven communications program). It is best to combine techniques, like MultiLink and many mainframe systems do.

Concurrency can degrade performance: because DOS does not provide overlapped disk I/O, running two programs concurrently usually takes much longer than running them one after the other. The exception is where one program spends most of its time waiting for a slow I/O device such as the keyboard or a serial port. Of course, the ability to switch rapidly among multiple applications can be useful even without true concurrency.

Unlike paged virtual memory, disk swapping does not increase the number of applications that concurrently execute. (Programs swapped out are suspended until they are restored.)

Table 1 would have been more useful if it also had listed the memory overhead for each partition. Obviously, partition overhead can limit the number of programs that fit into memory.

The author also missed some important aspects of the product:

DESQview does provide expanded keyboard buffering (table 1 is incorrect) and, like TopView, its scheduling algorithm normally gives a foreground program more time slices than a background program. Unfortunately, DESQview's time-slicing algorithm apparently can break down when dealing with certain types of foreground programs that sometimes lock out other concurrent programs (a serious problem if, for example, a communications file transfer is in progress in the background).

DESQview will not run any program properly that invokes a "child" process, such as a DOS shell. (Memory gets corrupted to the point that a cold reboot often is required.) This makes it impossible to execute a second copy of COMMAND.COM in a batch file.

DESQview fails to use the COMSPEC environmental string properly. It requires copies of COMMAND.COM in the root directory as well as its own.

Under DESQview, Print Screen does not always print the visible screen. (Sometimes the invisible foreground screen is printed.) In addition, DESQview's display management can exact a performance penalty of up to 50 percent for certain programs.

On the other hand, there is a lot to like about DESQview: compact size, batch file and extended memory support, TopView compatibility, disk swapping, elegant mark and transfer, and sophisticated keyboard macros. In fact, despite the problems mentioned above, I find it a useful tool and superior to TopView. (TopView's lack of support for redirection and batch files is a particularly glaring weakness.)

I do not share the author's enthusiasm for Windows. In the demonstrations I have observed, the nonpreemptive scheduling algorithm and bitmapped graphics resulted in painfully sluggish response. Windows also seems less capable than DESQview at running poorly-behaved programs concurrently.

I also think that the author was too kind to Concurrent PC-DOS. In my ex-

tensive testing, I found that its limitations and weaknesses made it virtually useless for IBM PC-DOS applications.

All of the concurrent environments need development. However, they may run out of time if the rumored multitasking DOS 4.0 becomes a reality.

John Navas II
Palo Alto, CA

When Mr. Navas says that time slicing is more efficient than nonpreemptive scheduling, he assumes that the overhead required by time-sliced task switching is greater than the time saved by optimizing tasks waiting for I/O, an assumption that is sometimes true.

I share Mr. Navas's enthusiasm for DESQview in comparison to TopView. My greater enthusiasm for Windows is based in part on its attempt to define a graphics user interface with sufficient features and performance characteristics to be useful to software developers and end users. The greater the functionality on the office desktop, the greater the need for a good interface for users who are not computer literate; the MS-DOS command-line input method is not acceptable in the long-term.

Further, the performance of the latest version of Microsoft Windows is equal or superior to the other packages tested, although demonstration of this fact is difficult: a common set of third-party software packages would not simultaneously run with all the concurrent environment packages tested. This left an apples-and-oranges situation for testing (the reason benchmarks were not run with the article).

However, if multitasking DOS 4.0 eventually becomes a reality, I will bet that Windows will remain a viable product in some form.

—Don Awalt

I enjoyed "Concurrent Environments," as it seemed to be both comprehensive and well-researched. Based on the author's conclusions, I recommended Windows to a friend. He then bought the package, primarily to be able to do other things while downloading from bulletin boards.

Imagine our dismay when we found that Windows does not multitask standard applications. Except for WinAps, it either suspends tiled applications or simply turns over control. This was confirmed by Microsoft. Therefore, except for special applications, Windows should not even be rated alongside true concurrent environments.

Because it seems so prejudicial, I cannot understand how such an important caveat could have been omitted. In the article, the discussion of different modes carefully avoids this issue, leaving the impression that Windows handles each kind of application to the greatest extent. In truth, no attempt is made to multitask anything except programs written to Microsoft's standard.

By this omission, you have misled many people into buying a package that does not do what it claims to do. In trying to understand the reviewer's viewpoint, my only guess is that for some reason, he failed to test the Windows package adequately beyond noticing that the initial screen was not in color. (A deception by Microsoft—the box shows a color EGA screen, but with a color graphics adapter. In 640-by-200 high-resolution mode, only black and white is possible).

I suggest that you check into this problem. If a review is biased or incomplete, software developers with superior products are hurt, and the public

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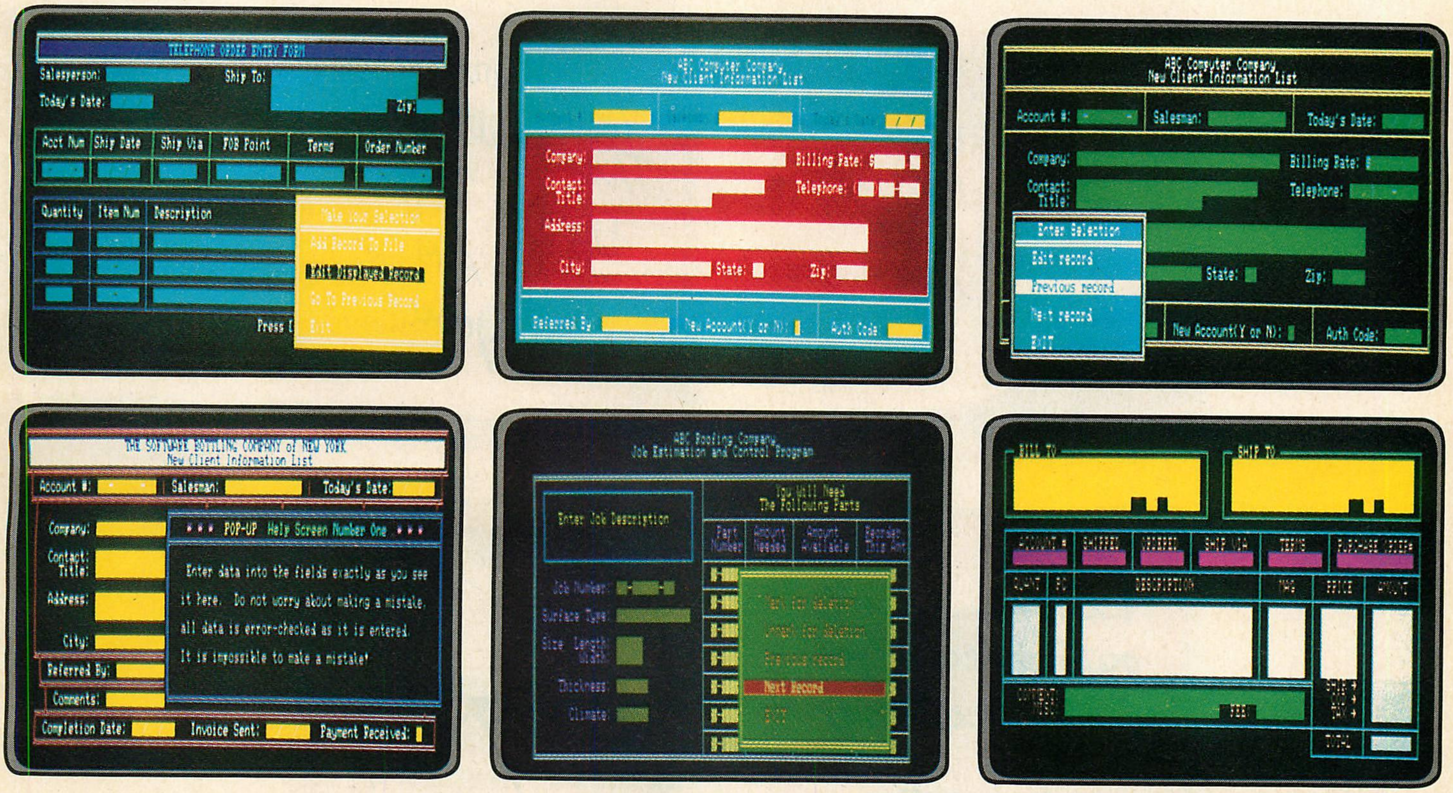

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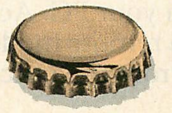

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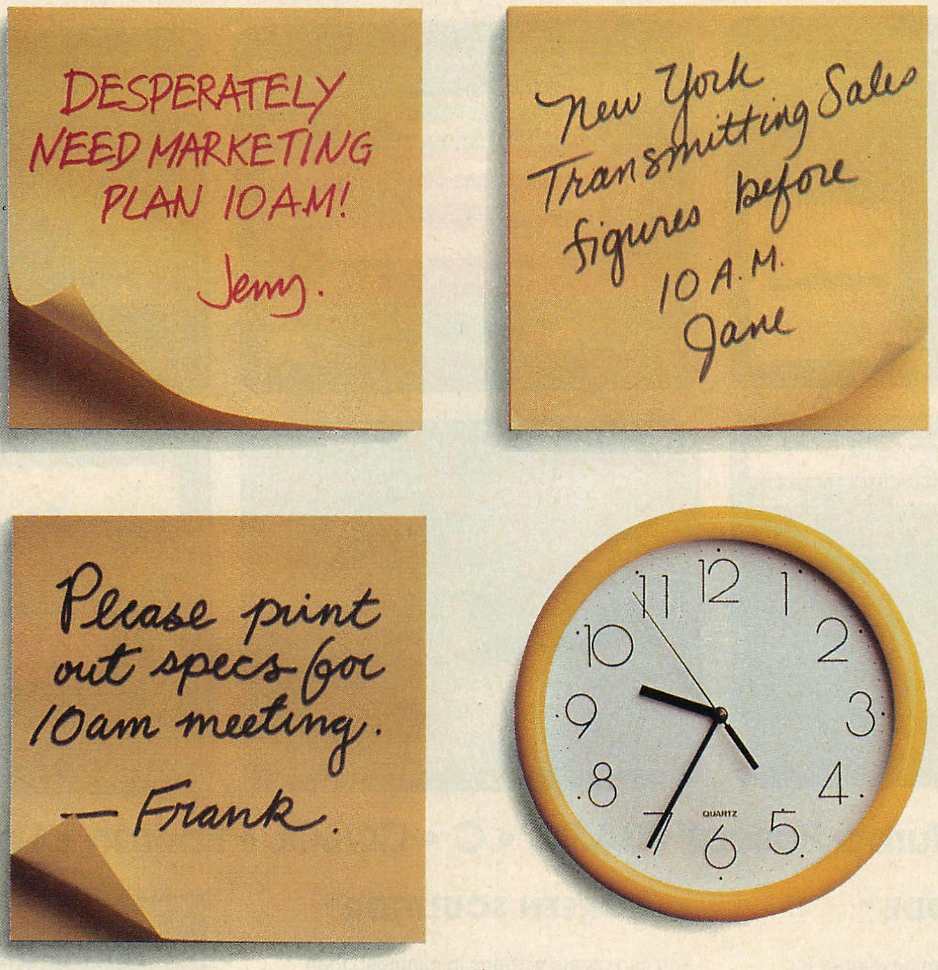

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is deceived. In this case, the damage already has been done, as the software press resounds with acclaims for the product Windows pretends to be.

Dan Magorian
Leesburg, VA

I strongly disagree with Mr. Magorian's statement that the Windows software is not what it pretends to be.

The article states that Windows can concurrently execute either WinAp applications or old applications that are "well-behaved," the major criteria for which is direct video I/O. Programs that do all video I/O through MS-DOS function calls, for example, can be executed concurrently (assuming no other characteristics render them ill-behaved).

My opinion that Windows is the "best package reviewed" stands. In addition to doing the best job with concurrency, Windows provides management of expanded memory for applications being written to the Lotus/Intel/Microsoft specification. Microsoft's involvement in the future of MS-DOS will ensure that WinAp remains compatible with future operating systems.

Windows also provides a graphics user interface that is superior to the command-line interface typified by MS-DOS. The power of Windows will enable users to have full cut-and-paste capability across all future applications; in addition, the use of graphics standards available through Windows will enable a broader set of printers, plotters, and displays to be supported in the future.

—Don Awalt

About two years before anyone had heard of Windows, I wrote an interactive, text-based BIOS- and DOS-compliant game for the PC in the DOS 1.0 environment. The .EXE for that file is unchanged after four years. With the proper settings in its .PIF file, Windows runs it in a window and concurrently. So, Mr. Awalt's statements are correct.

However, applications written without knowledge of Windows will run concurrently only when their window is visible on the screen: they will not run as icons (that is, in the background). This subtlety unfortunately was missed by Mr. Awalt, our technical staff, and our outside consultants.

We regret the omission and apologize for any inconvenience it caused.

—WF

REALTIME REVELRY

I would like to thank Richard M. Foard for his excellent review of the CX/PC

```
sub   ax,ax                       ;task_tbl[0..max_tasks - 1] = 0;
mov   cx,max_tasks                ;
mov   bx,offset task_tbl          ;

mov   bx, offset dgroup:task_tbl  ;
mov   ax,1                        ;task_tbl[0] = 1;
mov   [bx],ax                     ;
sub   ax,ax                       ;task_tbl[1..max_tasks - 1] = 0;
add   bx,2                        ;
mov   cx,max_tasks - 1            ;
```

Realtime Executive as part of the "Multitasking Methods" article (March 1986, p.57). He had a firm grasp of the central concepts, and he presented them clearly. As one of the main objectives of CX/PC is to teach realtime programming techniques, it was gratifying to see that the ideas could be transferred.

It is always a thrill to see software "come to life" in a realtime environment, similar to hearing a complex musical selection being played well.

I continue to make improvements to the Executive. In version 2.0, the files and documentation have been reorganized to make the material easier to understand and use. In addition, I am preparing a 68000 version.

Unfortunately, the INTR-Soft telephone number was given incorrectly. The correct number is 617/369-6242.

Walter S. Heath
INTR-Soft Company
Bedford, MA

*Thank you for the correction. We are sorry for any inconvenience it caused. We also would like to note corrections to the TJ/OS listing that appeared with this article. First, all occurrences of the expression offset **task_tbl** should be changed to offset **dgroup:task_tbl**. Second, the subroutine **_init_os** is incorrect. The zero entry of **task_tbl** must be initialized to a nonzero value for the procedure to work. The correction is shown in the figure above: the top set of lines is replaced by the bottom set. The corrected TJOS.ASM file also is available on PCTECHline.*

—CH

C MISINTERPRETATION

In this issue, your round-up review of C interpreters ("The State of C Interpreters," Marty Franz, p. 153) includes the interpreter that is part of our training system, Introducing C. This interpreter is an integral part of our training package, and was developed solely as an aid in the C learning process. To review it separately from the program's tutorial is taking it out of context.

The Introducing C interpreter was never, and never will be, designed as a professional program development tool. Rather, its sole purpose is to help people learn how to write good C, and write it correctly.

Because of this case of "mistaken identity," we request that, in a future issue of *PC Tech Journal*, you review Introducing C for what it is, an interactive C language training system, which includes a training manual, interpreter, and a specialized C function library tailored toward training.

George Eberhardt
President
Computer Innovations, Inc.

A PHONE CALL AWAY

Regrettably, our address and telephone number have been given incorrectly twice in your magazine: in our ad in the February 1986 issue (p. 195) and in your review of our product in the March 1986 issue (see "In the ISPF Tradition," Rudy S. Spraycar, p. 113). We are Heuristic Computer Systems, Inc., 853 Hickory Drive, Carmel, IN 46032-2307, 317/848-8981.

The HCS/Editor version used in the review will be one year old when this letter is published. The current HCS/Editor is not just the editor; it is now the same type of ISPF implementation as the other three products in the review. It is more like ISPF and includes a few more extentions to ISPF, such as macro support. We were hoping to be able to announce these items when poeple called in and sent in information requests. With the wrong phone number twice in a row and now the wrong address, you may have dealt us a severe blow—not deadly, just painful. Please exercise more care in the future.

Robert A. Fowler
President
Heuristic Computer Systems, Inc.

We sincerely regret these errors. We also must report that in connection with the same article, the correct telephone number for Arrix Logic Systems, Inc. is 416/292-6425; the company's toll-free number is 800/268-3599.

—WF

FOR C AND UNIX

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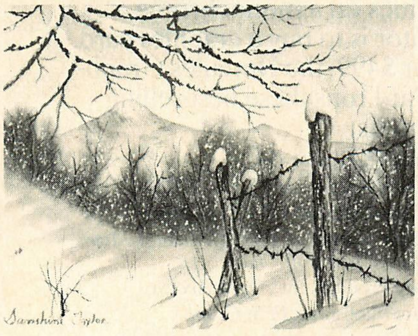

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*Steven Weiss, Stratford Systems (18 yrs; 1 yr)**

"WFC is the standard by which we judge all other C utilities. The most helpful tool we've ever acquired. Absolutely easy to use. Very tight code."
*James Baker, Mathew Bender (7 yrs; 4 yrs)**

*"Especially compared to **Panel,** I love **Windows for Data.** Your documentation is great."*
*Don Heinmeller, Law Software (10 yrs; 4 mo)**

"The documentation lets you get up and running fast. I integrated help routines into existing educational programs in a day and a half."
Richard Rovinelli, Educational Services (17 yrs; 1 yr)

**(programming experience; C experience)*

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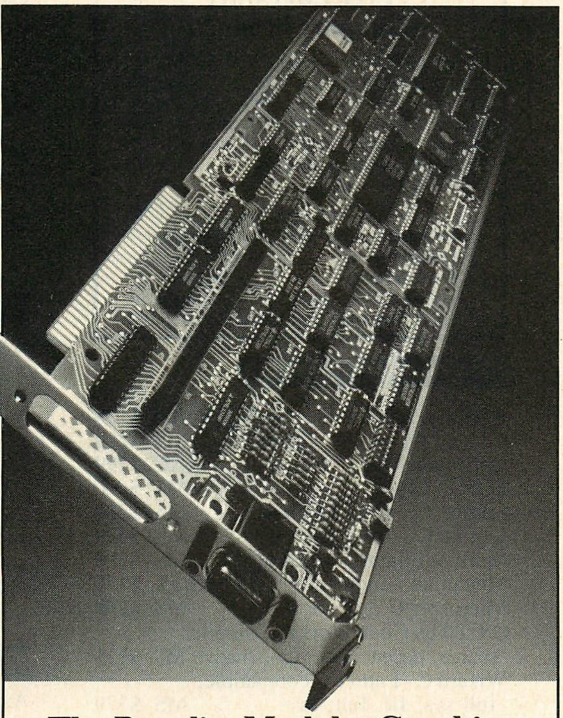
And some good news.



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MICROSOFT LANGUAGES NEWSLETTER Vol. 1, No. 5

News about the Microsoft Language Family

Microsoft® XENIX® Languages Offer Source Compatibility with MS-DOS®

Applications developed for MS-DOS using Microsoft high-level languages can easily be transported to XENIX. The XENIX versions of BASIC, C, COBOL, FORTRAN, Macro Assembler, and Pascal offered by Microsoft are source-language compatible with the MS-DOS versions.

The object files produced by C, FORTRAN, and Pascal can be used in either operating system environment, except for FORTRAN object files that access arrays greater than 64K in length. This makes it easier to move operating-system-independent subroutine libraries between systems.

Using MAKE to Replace Batch Files for Program Development

The MAKE utility provided with Microsoft Macro Assembler Version 4.0 can be used to replace batch files for building application programs. When using standard batch files to build an application every step has to be performed. However, with MAKE the time and date dependency rules allow recompiling, reassembling, or relinking only those files that are dependent upon recently changed files.

The MAKE utility also has rules and macros. These features provide an easy and reliable way to change how application programs are built. For instance, by defining a rule for how C files are compiled into object modules, every C compilation can be done with the same compiler options. When rules are combined with macros, new compilation options can be provided on the MAKE command line or in the MAKE file. If you regularly develop large programs and are not using a MAKE type of utility, you should investigate how it can help make your software development more efficient.

Cullinet's Micro/Mainframe Software Developed with Microsoft Macro Assembler

Cullinet's INFOGATE® and GOLDENGATE® software supports over a dozen ways of connecting PCs to mainframes running Cullinet's Information Center Management System. "The only way we could create this transparent link was with Microsoft Macro Assembler," said Mary Kroening, Director of Micro Software Development.

"Microsoft Macro Assembler's unique type checking and data structure features make it easy to connect routines with the rest of INFOGATE or GOLDENGATE. The Macro Assembler is an especially versatile product for writing device-level code to support LAN cards, 3278 emulation cards, SDLC interfaces, async ports, and more. The increased speed and reliability in Microsoft Macro Assembler 4.0 not only makes our job easier, but also cuts the build time in half."

For more information on the products and features discussed in the Newsletter,
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16011 NE 36th Way, Box 97017, Redmond, WA 98073-9717.
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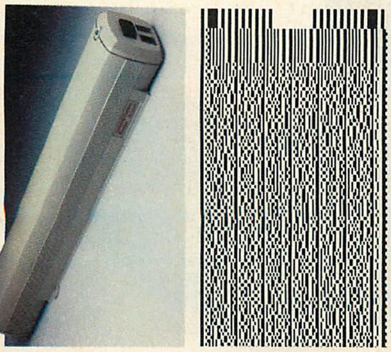
Look for the Microsoft Languages Newsletter every month in this publication.



The Softstrip System

The best reason yet to stop fighting paper and number it among effective means of data communications may be this paper-reading system.

For all the talk of the "paperless office," paper is still very much with us. The desktop computer has whetted the corporate appetite for information, and, in the absence of a mature national data network or even an accepted network *standard*, paper is the only universal channel for moving information from one set of hands to another. Even given the most optimistic estimates for network penetration over the next ten years, some people always will be beyond the network's reach. As a result, what needs to be done when building networks is to include in the topology an interface to paper—to make, in other words, better paper.

Two primary difficulties of reading data encoded on paper must be addressed. First, paper is an uneven medium, the quality of which is prone to disintegrate as the result of ink drop-out, smudging, dirt, and folding. In addition, any paper reader must tolerate inevitable sloppiness as the result of human handling. In its solution to these problems, Cauzin Systems has produced a data encoding/paper reading system that could add paper to the list of available channels in the corporate data network. *PC Tech Journal* has chosen the Cauzin Softstrip System as Product of the Month for May 1986.

A Softstrip is a variable-length pattern the width of a stick of gum that is marked with a small dot and line for reader alignment. The strip can contain many files, and a single logical strip can extend over any number of physical strips. A single printed 8½-by-11-inch page can store about 30KB of data at maximum density. In use, the reader is placed over the strip so that the alignment dot appears in the alignment hole, and the alignment line appears at the edge of the reader body. A scanning carriage within the reader traverses the strip and reads information under the control of a resident DOS utility, at a typical speed of 30 seconds per 5,500-byte, 9-inch physical strip. The reader automatically adapts its serial port baud rate to that of the host computer port to which it is attached.

The strips are extremely tolerant of discoloration—by coffee stains, skin oils, even ink—and the reader can be positioned as much as one-eighth-inch skewed to the strip itself before reading fails. The reader uses a near-infrared light source that "sees" carbon-based inks and ignores pigments not based on carbon black. A hardware parity system within the reader allows the reader to detect and correct up to two damaged bits per data strip line. The strip as a whole is checksummed for errors not detected on a line-by-line basis.

PRODUCT
The Softstrip System

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TELEPHONE
203/573-0150

PRICE
$199.95

Softstrips can be printed at different densities. The reader detects strip density on the fly and can read any legal strip without adjustment. Strips can be reproduced via high-quality xerography; the typical two- to four-percent enlargement on office copiers is not a problem. A program, which is sold separately for $19.95, creates low-density strips on an Epson graphics printer. Technology to produce higher density strips on laser printers and offset presses is patented and will be licensed to interested concerns.

Remarkably, two-color printing with a red logo *over* the black strip is used as a speed-bump form of copy protection against copiers. Most xerographic processes see red as black and will print the logo as obliterating noise. The reader ignores the original's red ink and sees only the black strip.

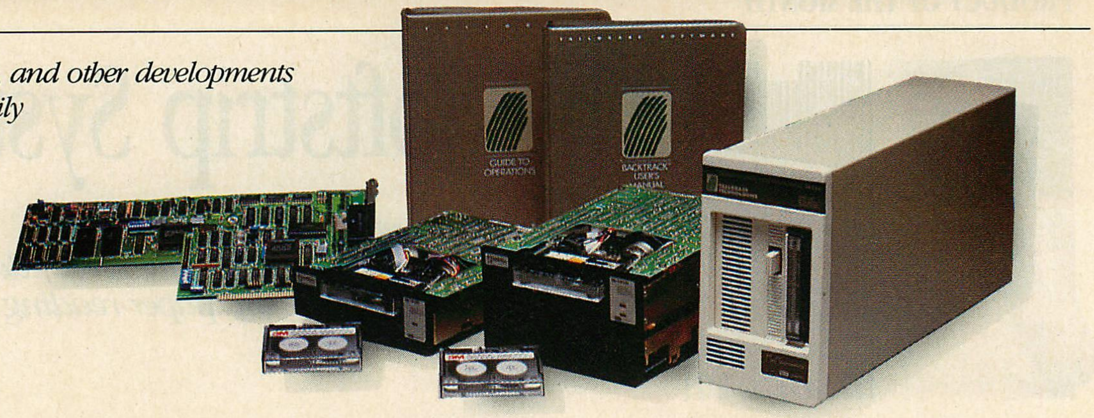
Cauzin Systems has been printing strip-encoded software in its magazine advertisements to drum up interest in the Softstrip System. Several upcoming computer books also will include example programs in strip form. The problem of the chicken versus the egg is severe; until a critical mass of readers is sold, the business computing community is unlikely to adopt the system.

It should be adopted, however. Paper enjoys a rare privilege of privacy when passing over national boundaries in first-class mail. Softstrips in first class correspondence are difficult to detect and can be encrypted to protect against interception. Within the United States, the mails are legally protected in ways that electronic communications are not. In addition, the product's immunity to magnetic fields and folding is further recommendation that mail or courier distribution of Softstrip data should be used between central and field offices.

Cash register tapes with Softstrips on the back, along with strips encoded on utility bills as well as checking and charge account statements, could make computerized family budgeting possible and provide the first genuine justification for a home computer. The reader does not have to be a separate peripheral; the technology could be built into point-of-sale terminals for easy processing of returns and warranty service.

Whether Cauzin succeeds in getting industry to adopt its keyless data entry standard is an open question, but the company has done its homework. The Softstrip System was designed for paper and understands paper's limitations. It is the best reason yet to add paper in a reasonable way to the growing network of data communications.

Hardware, software, and other developments for the IBM PC family



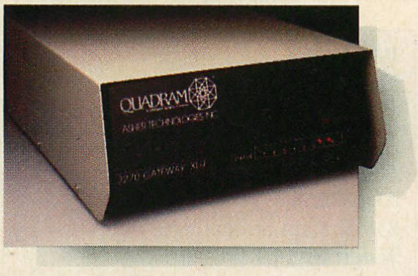
GRAPEVINE by CASE Communications

HARDWARE

FastPak, introduced by **AST Research, Inc.**, is an Intel 8086-based turbo card for the PC or PC/XT designed to accelerate the operation of applications, including those involving expanded-memory-specification software. FastPak includes an 8KB two-set cache that creates two buffers to hold portions of currently active applications programs. FastPak speeds operation by reducing the need for the 8086 to read program code or data from the PC system memory. Once active, the cache system checks to see if the required block of code is held in one of the buffers. If found, the code is executed; if not, a new block is moved from system memory into a buffer. Installation involves inserting the card into an expansion slot, removing the 8088 from the motherboard and inserting it into the FastPak card, and plugging a cable from the FastPak into the original 8088 socket. Users move from turbo to 8088 mode with a switch on the FastPak board. Under $500.
AST Research, Inc., 2121 Alton Avenue, Irvine, CA 92714; 714/863-1333
CIRCLE 304 ON READER SERVICE CARD

The **SMF/AT210-4M**, a multifunction module designed to upgrade the PC/AT to a multiuser system, is now compatible with XENIX and UNIX systems, in addition to DOS. This module, from **Sigma Information Systems**, provides from 256KB to 4MB of memory and supports two to seven serial line devices (including the console terminal) and a parallel printer. The SMF/AT210-4M plugs into one PC expansion slot and operates at speeds of up to 9600 baud. With 256KB of memory, 2 serial ports, and 1 parallel port, $464.
Sigma Information Systems, 3401 E. La Palma Avenue, Anaheim, CA 92806; 714/630-6553
CIRCLE 322 ON READER SERVICE CARD

Quadram Corporation has announced the **Quad3270 Gateway XLU**, a combined hardware and software product that supports communication between LAN-based PCs and mainframe hosts. The XLU supports PC to SNA mainframe communication by enabling the PC to emulate IBM 3278 model 2 and 3279 two- and four-color terminals. As many as 64 host mainframe sessions can be conducted concurrently. The product also provides a modem pool function, permitting multiple PCs to share its available asynchronous modems for PC-to-asynchronous host communication. Its hot-key feature allows users to toggle between SNA and asynchronous host sessions and normal operation. The XLU can accommodate up to three different types of LANs concurrently and provides for LAN-to-LAN communications. 8 LUs, $6,818; 16 LUs, $7,485; 32 LUs, $8,182; 64 LUs, $9,485.
Asher Technologies, Inc. (Quadram's communications products division), 1009 Mansell Road, Roswell, GA 30076; 404/993-4590
CIRCLE 306 ON READER SERVICE CARD



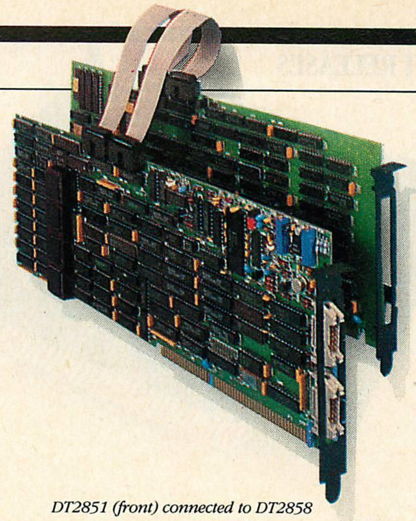
Quad3270 Gateway XLU by Quadram

GRAPEVINE is a cost-effective LAN designed to interconnect terminal devices and computer resources within a building or site. Introduced by **CASE Communications, Inc.**, the system uses data-voice multiplexing techniques so that data traffic shares the existing telephone wiring without interfering with or interrupting normal speech usage. An optional central data exchange can provide access to multiple computer resources or gateways to wide area networks, private or public, and specialized host computer environments, such as IBM. At the terminal location, a small access unit is plugged into the telephone jack; both the terminal and the telephone handset plug into this unit. Data rates up to 19.2 kilobits per second, asynchronous or synchronous, are possible on the standard internal telephone wiring. $235.
CASE Communications, Inc., 2120 Industrial Parkway, Silver Spring, MD 20904; 301/381-2300
CIRCLE 316 ON READER SERVICE CARD

A low-cost LAN that provides basic networking services among interconnected microcomputer workstations has been introduced by **Xerox Corporation**. The network, called **Xerox Communications 24 (XC 24)**, combines a 10 megabit-per-second network with a low installation cost and an intuitive user interface. The network connects 30 Xerox 6060 family workstations or DOS 3.1-based PCs over a 600-foot cable segment and 900 devices with additional cabling and repeaters. XC 24 offers several options for sharing hard disks, files, and printers among networked workstations. $720 per connection.
Xerox Corporation, Xerox Square 006, Rochester, NY 14644; 716/423-5078
CIRCLE 313 ON READER SERVICE CARD

A hardware/software data acquisition system has been introduced by **Cyborg Corporation**. Designed for research and development, product testing, and process monitoring, the **ISAAC 5000** hardware addresses the need for flexibility, ease of use, and future upgrades. The system incorporates eight slots for any of Cyborg's I-series of interface cards. ISAAC 5000 features **Discovery**, a menu-driven applications tool with graphic displays of data for acquisition and

ISAAC 5000 by Cyborg Corporation

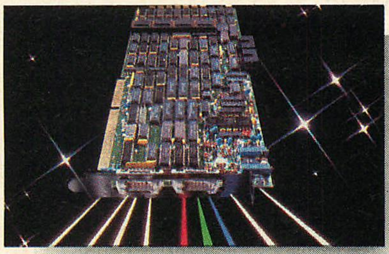


DT2851 (front) connected to DT2858

analysis. Discovery generally eliminates the need for programming; where programming is necessary, the **LabSoft programmer's toolkit** is available for BASIC, C, and FORTRAN. The **high-speed option** can be added to the base unit as applications requirements increase. The high speed module can handle from 1 channel to more than 1,000 and from 1 sample an hour to 200,000 samples per second. Four channels of high-performance A/D are standard with this option; additional channels and buffer memory can be added. The module provides for IEEE-488 communication to the PC host. ISAAC 5000, $1,800; ISAAC/IBM interface card, $350; Discovery, $1,190; LabSoft, $500; high speed option, $4,850; modular expansion boards, $500 to $2,450.
Cyborg Corporation, 55 Chapel Street, Newton, MA 02158; 800/343-4494; in Massachusetts, 617/964-9020
CIRCLE 305 ON READER SERVICE CARD

Intel Corporation has introduced a hardware card and software development package that halves evaluation time for Intel's 4MB magnetic bubble memory components. The **PC-Bubble Card** includes either 512KB or 1MB of bubble memory in addition to the **4-SITE** software, an interactive program that enables designers to learn quickly how to program the 7225 bubble memory controller. Two versions of the PC-Bubble Card are available. The PCB-75-1 has a single 7114 4MB bubble memory component; the PCB-75-2 has two bubble memory components. The two-bubble version is for users designing systems that incorporate two or more 4MB components with a single controller. The 7225 will support up to eight 7114 components, providing a total of 4MB of reliable, nonvolatile storage. PCB-75-1, $495; PCB-75-2, $795.
Intel Corporation, 3065 Bowers Avenue, Santa Clara, CA 95051; 800/548-4725
CIRCLE 310 ON READER SERVICE CARD

An advanced image processor that can achieve minicomputer throughput speeds on the IBM PC/AT has been announced by **Data Translation, Inc.** The **DT2851 High Resolution Frame Grabber** digitizes, stores, processes in realtime, and displays video images in monochrome or RGB false color at a rate of 30 image frames per second. System performance can be maximized with the addition of the **DT2858 Auxiliary Frame Processor**, a 16-bit pipelined processor that connects directly to the frame grabber over special I/O ports



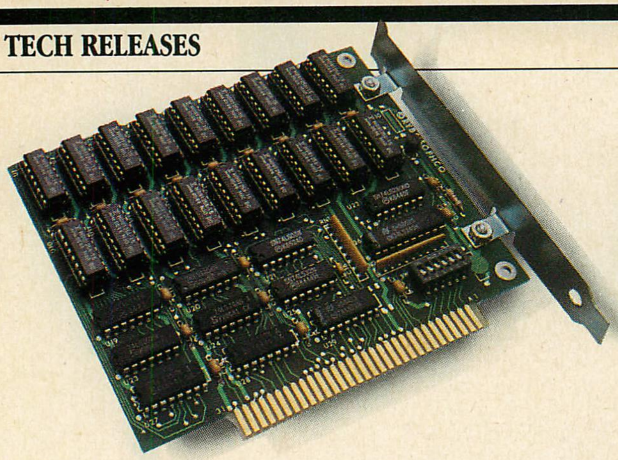
DT2851 High Resolution Frame Grabber

and speeds the completion of lengthy image processing calculations. The **DT-IRIS Image Processing Software** implements image processing algorithms on the DT2851 and the DT2858 to help increase process execution speed on the AT. DT-IRIS is composed of two sections: IRIStutor, a tutorial program, and IRISsub, a library of image processing subroutines. DT2851, $2,995; DT2858, $1,495; DT-IRIS, $995.
Data Translation, Inc., 100 Locke Drive, Marlboro, MA 01752; 617/481-3700
CIRCLE 301 ON READER SERVICE CARD

A hardware/software package that enables a PC/XT or PC/AT to monitor and analyze the activity of any LAN that adheres to the IEEE 802.3 standard has been introduced by **Excelan Inc.** The **LANalyzer EX 5000E** permits network systems developers to debug LAN applications and protocols. Its open architecture permits OEMs and large end users to develop test routines for specific LAN requirements. The LANalyzer permits the capture and analysis of data according to predefined criteria independent of protocols such as TCP/IP, DECNet, XNS, or ISO. Realtime test results are displayed in bar graphs and saved to a DOS file. $9,500.
Excelan Inc., 2180 Fortune Drive, San Jose, CA 95131; 408/434-2226
CIRCLE 309 ON READER SERVICE CARD

PC Technologies, Inc. has announced the release of its **286 Express accelerator card** for the PC and PC/XT. This half-slot card is powered by Intel's 80286 8-MHz microprocessor; it requires no new or bundled memory and needs no special operating software. A unique 8KB cache memory provides zero wait access to the most recently used code and data. That same feature allows a stock PC to accelerate 700 percent; if the cache is disabled, acceleration still is at least 200 percent. $795.
PC Technologies, Inc., 704 Airport Blvd., Ann Arbor, MI 48104; 800/821-3086; 313/996-9690
CIRCLE 318 ON READER SERVICE CARD

A new product that provides hardware-assisted debugging has been announced by **Microtech International**. The hardware, called **BUG ZAPPER**, consists of an expansion board that features a ZAP circuit and a HALT button. The ZAP circuit traps bugs as they overwrite critical memory locations. The HALT button enables users to interrupt programs at the touch of a button. The package's GUARDIAN software loads into memory at boot time, but remains dormant until activated via the HALT or ZAP button. In addition to the normal debug commands, GUARDIAN provides a facility for arming the ZAP circuit. $195.
Microtech International, 9906 Norwood Court, Dept. Z-2, Largo, MD 20772; 301/350-1068
CIRCLE 317 ON READER SERVICE CARD



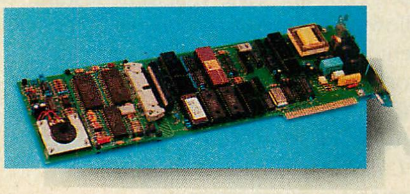
RYBS Electronics' HiCard

MicroSpeed's Fast88

HiCard, a short-slot, ½MB RAM card that addresses up to 896KB of memory, has been introduced by **RYBS Electronics, Inc.** Through an arrangement with **Sophco, Inc.**, this product comes packaged with **HiPage utility software**, which takes full advantage of the expanded memory by accessing 740KB of DOS memory plus an additional 192KB of electronic disk and spooler space. With 256KB, $159; with 512KB, $199. *RYBS Electronics, Inc., 2510 N. 47th Street, Suite HH, Boulder, CO 80301; 303/444-6073*

CIRCLE 308 ON READER SERVICE CARD

Telenetics Corporation has added a 9600-bps modem to its ExpressData line. The **ExpressData 96** is available in both external and internal versions. Basic features include auto answer, auto



Telenetics' ExpressData 96 internal modem

dial, call monitoring, Hayes command set compatibility, phone number storage, remote diagnostics, voice-to-data transmission switching, automatic adaptive equalization, bisynchronous error control, and V.29 compatibility. $1,595. *Telenetics Corporation, 895 E. Yorba Linda Blvd., Placentia, CA 92670; 714/524-5770*

CIRCLE 321 ON READER SERVICE CARD

Tallgrass Technologies Corporation has announced a new line of internal tape and disk/tape subsystems. The **TG-1020i** is an internally mounted, half-height, 5¼-inch tape drive that backs up 20MB of data on a DC-2000 tape cartridge. The **TG-2025i** is an internally mounted, full-height, 5¼-inch 25MB hard disk with a 20MB tape drive that backs up data on a DC-2000 tape cartridge. The **TG-1425i** is an internal, 3½-inch 25MB hard disk with a half-height, 5¼-inch tape drive that stores 20MB of data on a DC-2000 tape cartridge. The new internal drives include two software programs: XTREE, a menu-driven file and directory management software program, and BackTrack, a software-based automated hard disk backup system. TG-1020i, $995; TG-2025i, $1,995; TG-1425i, $2,095. *Tallgrass Technologies Corporation, 11100 W. 82nd Street, Overland Park, KS 66214; 913/492-6002*

CIRCLE 320 ON READER SERVICE CARD

A speed enhancement product for the PC, PC/XT, and compatibles that offers an increase in performance of up to 60 percent with 100 percent software and hardware compatibility has been announced by **MicroSpeed Inc.** The **Fast88** replaces the standard 8088 CPU with a higher speed 8088-2 (or optional NEC V20 enhanced CPU) and allows the user to switch between the normal 4.77-MHz system clock and a selectable frequency clock generator of 6.1 MHz, 6.7 MHz, or 7.4 MHz. These frequencies improve performance by 30, 45, and 60 percent, respectively. It works with many popular software products. $149.95; with the NEC V20, $189.95. *MicroSpeed Inc., 5307 Randall Place, Fremont, CA 94538; 415/490-1403*

CIRCLE 303 ON READER SERVICE CARD

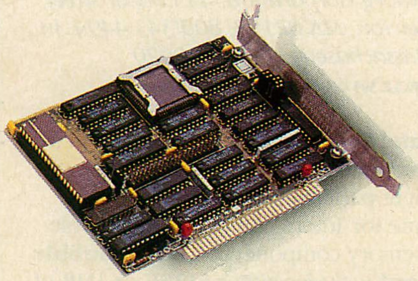
Techland Systems Inc. and **Missing Link Computer Technology**, Inc. have announced the first PC-to-mainframe link that allows PC users to enter and retrieve information by voice using a telephone located anywhere in the world. A combination of Missing Link's **"TALK TO ME"** system and Techland's **BlueLynx 5251/model 11** allows complete voice I/O and telephone management between the PC line and System/34. Software provided allows "TALK TO ME" to be linked to any host computer. This gives the system access to any existing database and, thus, the ability to run all existing software by voice and through a telephone. Package, $4,795. *Techland Systems Inc., 25 Waterside Plaza, New York, NY 10010; 212/684-7788*

CIRCLE 314 ON READER SERVICE CARD

Missing Link Computer Technology, Inc., 34-20 45th Street, Long Island City, NY 11101; 718/937-9334

CIRCLE 315 ON READER SERVICE CARD

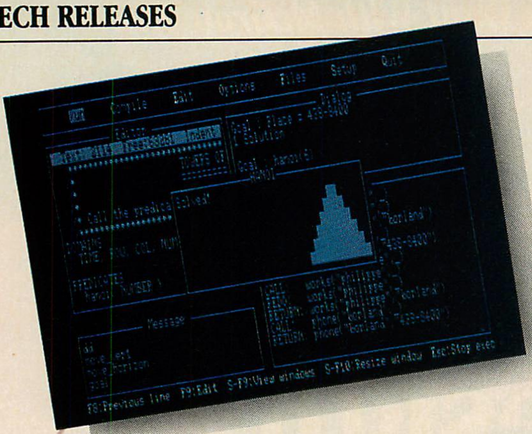
A plug-in card that runs software up to six times faster than normal with no modification to the software has been announced by **Mountain Computer, Inc.** The **RaceCard-286** fits into the short slot in any computer; it is compat-



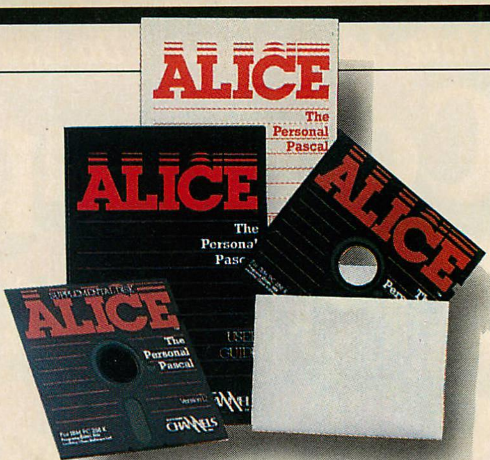
RaceCard-286 by Mountain Computer

ible with almost all AT software, RAM, and peripheral cards, because it emulates the IBM 8088 native processor. This half card, which measures 5 inches by 3.9 inches, uses only seven watts of power from the computer's power supply. Among network packages, it supports the 3COM EtherSeries, Novell, Orchid PCNet, and STARLAN. Some communications software (such as Crosstalk and TelPak) and several word processing packages also can benefit. $795. *Mountain Computer, Inc., 360 El Pueblo Road, Scotts Valley, CA 95066; 800/458-0300; in California, 800/821-6066*

CIRCLE 319 ON READER SERVICE CARD

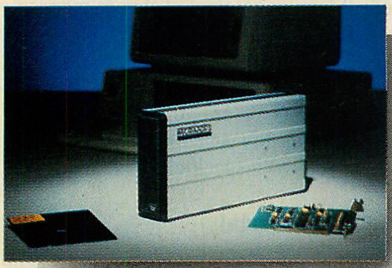


Borland Turbo Prolog screen



A new Pascal implementation by Software Channels

Pacific Micro Systems has announced the **Pelican 3.3**, a mass storage system that incorporates the Kodak 3.3MB half-height drive into an aluminum housing. The system includes a half-slot controller card and cache software to decrease data access time. The Kodak drive can access data in half the time of conventional 5¼-inch floppy disks. In addition, when presenting data, the Pelican software can achieve RAM disk speeds by utilizing part of the PC main memory as a cache data buffer to speed up programs that repeatedly reference the same data. The Pelican permits floppy-disk users to put multidisk programs on one diskette and to expand storage in 2.78MB segments, as needed. $795.
Pacific Micro Systems, 160 Gate 5 Road, Sausalito, CA 94965; 415/331-2525
CIRCLE 312 ON READER SERVICE CARD



By Pacific Micro Systems

Designed to fit in a single expansion slot of the PC or PC/XT, **OnBoard** is a high quality hard-drive system available in 10MB and 20MB versions. Introduced by **Maynard Electronics**, the board can control two hard drives. Thus, when OnBoard is placed in an XT as the system's second drive, it controls both drives, eliminating the need for the original controller board. 10MB version, $975; 20MB version, $1,195.
Maynard Electronics, 460 E. Semoran Blvd., Casselberry, FL 32707; 305/331-6402
CIRCLE 311 ON READER SERVICE CARD

SOFTWARE

The ORACLE relational database management system (DBMS) has been chosen by IBM for licensing on the RT/PC. Under the terms of the agreement between **Oracle Corporation** and **IBM Corporation**, IBM will market for the RT/PC a version of ORACLE as well as several fourth-generation tools which also are developed by Oracle. The ORACLE DBMS will be called **SQL/RT** by IBM. Included in the SQL/RT package are the SQL-compatible relational DBMS and a novice user's interface called **Easy SQL/RT**. This interface employs a point-and-select, menu-based interface and can create tables and generate reports. The SQL/RT package also includes an interactive command interface, an SQL precompiler for programs written in C, and an on-line data loader for the DBMS. SQL/RT, $1,000.
Oracle Corporation, 20 Davis Drive, Belmont, CA 94002; 800/345-DBMS; in California, 415/598-8000
CIRCLE 329 ON READER SERVICE CARD
IBM Corporation, contact the local IBM dealer; 800/426-2468
CIRCLE 330 ON READER SERVICE CARD

A Pascal programming environment introduced by **Software Channels, Inc.**, **ALICE** is based on a syntax-directed editor that understands the rules and structures of programming languages. ALICE provides a menu of templates from which the programmer can choose to build and edit programs; he simply fills in the blanks. ALICE contains a complete Pascal interpreter that includes program debugging tools. Users can watch program output and execution on the same screen. An extensive help facility of more than 500 screens is included. $95.
Software Channels, Inc., Four Kingwood Place, Kingwood, TX 77339; 713/359-1024
CIRCLE 339 ON READER SERVICE CARD

Borland International, Inc. has announced its fifth-generation language development system, **Turbo Prolog**. Turbo Prolog's incremental compiler generates native code, linkable object modules, and a linking format compatible with the DOS linker; it supports a flexible, object-oriented system. The interactive full-screen editor automatically positions the cursor at the source code point of an error. Programs can call the editor, and view and modify the program's source code at runtime, providing truly interactive development. Windowing support for text and graphics allows the programmer to move back and forth through windows for the editor, the trace facility, the source code listing, and sample query. $99.95.
Borland International, 4585 Scotts Valley Drive, Scotts Valley, CA 95066; 408/438-8400
CIRCLE 341 ON READER SERVICE CARD

An Ada compiler for the PC family has been introduced by **Artek Corporation**. Artek Ada meets all defense specifications for Ada, with the exception of tasking, and runs under DOS on computers with at least 384KB of memory. The compiler features generic subprograms, array and record aggregates, operator overloading, and dynamic arrays and exceptions. It requires only a single pass over the source code to produce executable pseudocode. The user can invoke a second pass of the compiler to translate this pseudocode into machine language for the 8086. Artek Ada also provides functions traditionally assigned to library managers and linkers. The Artek system includes a compiler, a full-screen editor, an interpreter/debugger, a linker/library manager, and a pseudocode disassembler. $895; demo disk, $29.95.
Artek Corporation, 100 Seaview Drive, Secaucus, NJ 07094; 800/PC-ARTEK; in New Jersey, 201/867-2900
CIRCLE 335 ON READER SERVICE CARD

Turbo Pascal and the Turbo Pascal family give you a perfectly integrated programming environment and unbeatable speed, power, and price

Turbo Pascal® is *faster* than any other Pascal compiler, and at only $69.95, a distinctly better deal. But it offers much more than speed, power, and price.

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☐ **Turbo Database Toolbox** is a perfect complement to Turbo Pascal. It includes a complete library of Pascal procedures that allows you to search and sort data, and build powerful database applications.

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☐ **Turbo Tutor** teaches you step by step how to use Turbo Pascal, with commented source code for all program examples on diskette.

Save $109.70 when you choose the Turbo Jumbo Pack. 6 different Turbo Pascal products for only $245.00!

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***NEW!** Amazing value! Turbo Editor Toolbox includes MicroStar,™ a full-blown editor that also does windows!* **Turbo Editor Toolbox** not only gives you ready-to-compile source code and a 200-page manual that tells you how to integrate the editor procedures and functions into your programs, but also includes MicroStar, a complete editor with full windowing capabilities. (You could pay $100.00 or more for a program like MicroStar, but you get it free as part of our Turbo Editor Toolbox.) You can also use Turbo Editor (which of course integrates with Turbo Lightning™) to build your own word processor!

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Turbo GameWorks also includes ready-to-play Chess, Bridge, and Go-Moku—an ancient Japanese game that can divert you from reality for hours on end.

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Jeff Duntemann, PC Magazine

Turbo Pascal has got to be the best value in languages on the market today
Jerry Pournelle, BYTE Magazine

This compiler, produced by Borland International, is one of the best programming tools presently available for the PC"
Michael Covington, PC Tech Journal

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___	Turbo Pascal w/8087, BCD††	$124.95	$______
___	Turbo Database Toolbox	$54.95	$______
___	Turbo Graphix Toolbox†	$54.95	$______
___	Turbo Tutor	$34.95	$______
___	Turbo Editor Toolbox†	$69.95	$______
___	Turbo GameWorks†	$69.95	$______
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Minimum System Requirements:
Turbo GameWorks, Turbo Graphix Toolbox, & Turbo Editor Toolbox—192K. All other products, 128K.
†IBM PC, PCjr, AT, XT, and true compatibles.
††16-bit only.

TF6

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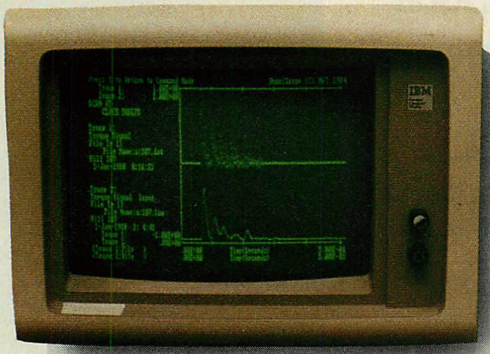
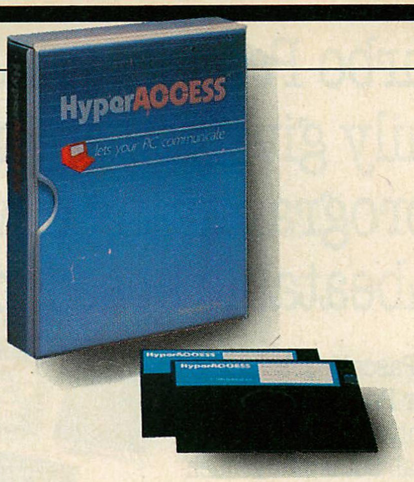


UnkelScope screen by Unkel Software



By Hilgraeve, Inc.

A software package that allows communications through modems or cables with almost any other computer has been announced by **Hilgraeve, Inc. HyperACCESS** gives users access to information utilities, computerized services, bulletin boards, microcomputers, or mainframes. It transfers files using XMODEM, Kermit, or a variety of text-transfer methods and can emulate such terminals as the DEC VT-52, VT-100, TeleVideo 900, IBM 3101, H-19, and TTY. HyperACCESS enables a computer to act as an unattended host, so it can be operated from any remote computer or terminal. Its powerful script language allows the user to create custom functions, prompts, and menus. $149.
Hilgraeve, Inc., P.O. Box 941, Monroe, MI 48161; 313/243-0576
CIRCLE 324 ON READER SERVICE CARD

DSD86, a new debugging program from **Soft Advances**, features a full-screen display built on a windowing system that allows the user to arrange and size displays. The macro facility can accept parameters and call other macros recursively. DSD86 can bind any command line to any Ctrl, Alt, or function key. The debugger offers full support for symbols from MAP files. $69.95.
Soft Advances, P.O. Box 49473, Austin, TX 78765; 512/478-4763
CIRCLE 331 ON READER SERVICE CARD

Chalcedony Software, Inc. has announced a large memory model Prolog interpreter called **PROLOG V-plus**. Features include 100 predefined predicates and operators, double-precision floating-point arithmetic, arithmetic functions, access to 640KB of RAM, the ability to call other programs from within PROLOG V-plus, and addressable cursor and graphics functions. $99.95.
Chalcedony Enterprises, 5580 La Jolla Blvd., Suite 126, La Jolla, CA 92037; 619/483-8513
CIRCLE 328 ON READER SERVICE CARD

The **PC Workbench**, a CAE software package that provides a complete set of analog/circuit design tools on a PC, has been introduced by **Analog Design Tools, Inc.** PC Workbench lets the designer construct a circuit, attach simulated test instruments, and see test results on a screen. Software functions include a circuit editor, three test setups, spectral analysis, parameter entry, parametric plotting, subcircuits, and statistical analysis. PC Workbench runs SPICE PLUS, an enhanced version of SPICE 3 software, which features a menu-based user interface with multiwindowing. The PC Workbench package includes a 32032 32-bit processor board that runs under UNIX System V and provides 2MB of memory for SPICE PLUS. The package also includes a mouse and seven software modules. $12,500.
Analog Design Tools, Inc., 66 Willow Place, Menlo Park, CA 94025; 415/328-0780
CIRCLE 325 ON READER SERVICE CARD

PC Workbench screen by Analog Design Tools

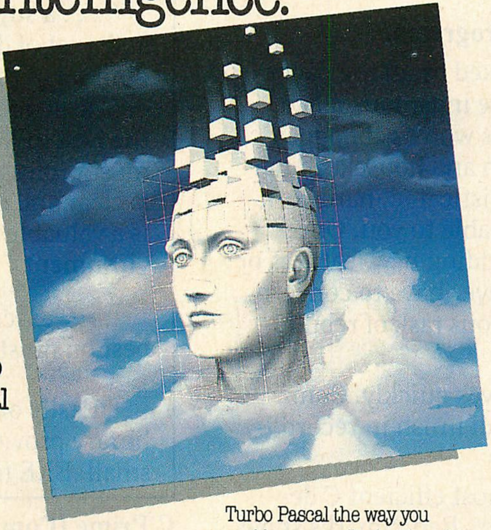
The Scientific Desk, designed for use with the PC, is now also available for the new RT/PC. Produced by **C. Abaci, Inc.**, The Scientific Desk is a problem-solving environment for scientific users. Programs, documentation, tutorials, and examples are integrated in a scope-oriented, menu-driven form. Functions and subroutines that cover the areas of arithmetic, error analysis, mathematical physics, linear algebra, interpolation, solution of nonlinear equations, and optimization are included for programming. In addition, problem solvers, which require no programming, are included. These cover approximation, eigenstate analysis, zeros of polynomials, singular value decomposition, and over-determined system solving. Annual site license fee, $1,320; purchase fee for one machine, $660.
C. Abaci, Inc., 208 St. Mary's Street, Raleigh, NC 27605; 919/832-4847
CIRCLE 323 ON READER SERVICE CARD

An encryption utility called **The Private Line**, released by **EVERETT ENTERPRISES**, is a DOS implementation of the Data Encryption Standard; it can encrypt any DOS file. Features include single- or double-file encryption and decryption; capabilities for text file print, file display, file purge, sorted disk directory display; and the ability to convert between binary and ASCII files. In addition, the user can specify one or two 64-bit keys. $49.95.
EVERETT ENTERPRISES, P.O. Box 193, Bath, NC 27808; 919/923-5621
CIRCLE 327 ON READER SERVICE CARD

A science and engineering laboratory software tool has been announced by **Unkel Software, Inc.** The **UnkelScope** is a data acquisition, display, processing, and control package. Level 1 presents a menu-driven interface that can accept and display data in realtime and store data for later analysis. Level 2 adds experiment control, process controllers, digital filtering, FFT-related functions, calibration, conversion, and algebraic functions. UnkelScope is compatible with data acquisition boards from Tecmar, MetraByte, and Data Translation. Level 1, $325; Level 2, $495.
Unkel Software, Inc., 62 Bridge Street, Lexington, MA 02173; 617/861-0181
CIRCLE 326 ON READER SERVICE CARD

Step-by-step tutorial, demo programs with source code included!

Borland introduces Turbo Prolog, the natural language of Artificial Intelligence.



Prolog is probably the most powerful computer programming language ever conceived, which is why we've made it our *second* language—and "turbocharged" it to create Turbo Prolog.™

Our new Turbo Prolog brings supercomputer power to your IBM® PC and introduces you step-by-step to the fascinating new world of **A**rtificial **I**ntelligence. And does all this for an astounding $99.95.

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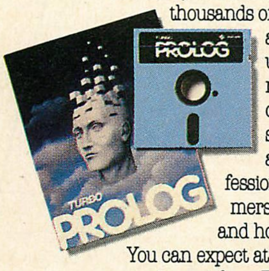
Our Turbo Pascal astonished everyone who thought of Pascal as "just another language." We changed all that—and now Turbo Pascal is the de facto worldwide standard, with hundreds of thousands of enthusiasts and users in universities, research centers, schools, and with professional programmers, students, and hobbyists.



You can expect at least the same impact from Turbo Prolog, because while Turbo Prolog is the most revolutionary and natural programming language, it is also a complete development environment—just like Turbo Pascal.

Turbo Prolog radically alters and dramatically improves the brave new world of artificial intelligence—and invites you into that fascinating universe for a humanly intelligent $99.95.

Even if you've never programmed before, our free tutorial will get you started right away

You'll get started right away because we have included a complete step-by-step tutorial as part of the 200-page Turbo Prolog Reference Manual. Our tutorial will take you by the hand and teach you everything you're likely to need to know about Turbo Prolog and artificial intelligence.

For example: once you've completed the tutorial, you'll be able to design your own expert systems utilizing Turbo Prolog's powerful problem-solving capabilities.

Think of Turbo Prolog as a high-speed electronic detective. First you feed it information and teach it rules. Then Turbo Prolog "thinks" the problem through and comes up with all the reasonable answers—almost instantly.

If you think that this is amazing, you just need to remember that Turbo Prolog is a 5th-generation language—and the kind of language that 21st century computers will use routinely. In fact, you can compare Turbo Prolog to Turbo Pascal the way you could compare Turbo Pascal to machine language.

You get the complete Turbo Prolog programming system for only $99.95

You get a complete Turbo Prolog development system including:

- The lightning-fast Turbo Prolog incremental compiler and the interactive Turbo Prolog editor.
- The 200-page reference manual which includes the step-by-step Turbo Prolog tutorial.
- The *free* GeoBase™ natural query language database including commented source code on disk—ready to compile. GeoBase is a complete database designed and developed around U.S. geography. It includes cities, mountains, rivers, and highways, and comes complete with natural query language. Use GeoBase immediately "as is," or modify it to fit your own interests.

So don't delay—don't waste a second—get Turbo Prolog now. $99.95 is an amazingly small price to pay to become an immediate authority—an instant expert on artificial intelligence! The 21st century is only one phone call away.

Turbo Prolog 1.0 Technical Specifications

Programming System Features

- ☑ ***Compiler:*** Incremental compiler generating native in-line code and linkable object modules. The linking format is compatible with the PC-DOS linker. Large memory model support. Compiles over 2500 lines per minute on a standard IBM PC.
- ☑ ***Interactive Editor:*** The system includes a powerful interactive full-screen text editor. If the compiler detects an error, the editor automatically positions the cursor appropriately in the source code. At run-time, Turbo Prolog programs can call the editor, and view the running program's source code.
- ☑ ***Type System:*** A flexible object-oriented type system is supported.
- ☑ ***Windowing Support:*** The system supports both graphic and text windows.
- ☑ ***Input/Output:*** Full I/O facilities, including formatted I/O, streams, and random access files.
- ☑ ***Numeric Ranges:*** Integers: −32767 to 32767; Reals: 1E−307 to 1E+308
- ☑ ***Debugging:*** Complete built-in trace debugging capabilities allowing single stepping of programs.

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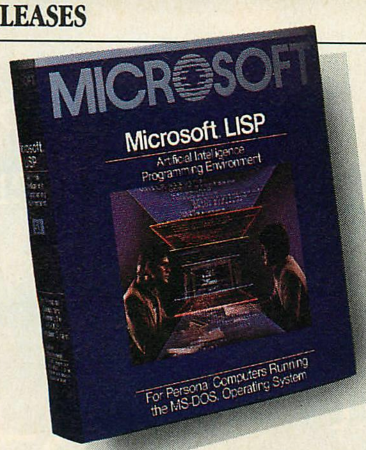

Version 5.1 of Microsoft LISP

Intel's Product Guide collection

Microsoft Corporation has announced **LISP version 5.1**. This update of the muLISP software created by Soft Warehouse, Inc. includes a greater number of primitives, expanded memory capacity (up to 512KB), support for Common LISP, expanded arithmetic capabilities, an improved symbolic debugger, faster list sorting, and split-screen capabilities. $250; upgrade for muLISP, $100.
Microsoft Corporation, 10700 Northup Way, Box 97200, Bellevue, WA 98009; 206/828-8080
CIRCLE 334 ON READER SERVICE CARD

LET'S C from **Mark Williams Company** is a complete implementation of the C language that includes recent extensions to C, a standard library, full UNIX compatibility, and English language error messages. LET'S C features a MICROEMACS full-screen editor and source code. $75.
Mark Williams Company, 1430 W. Wrightwood Avenue, Chicago, IL 60614; 312/472-6659
CIRCLE 336 ON READER SERVICE CARD

The entire **Visual Engineering, Inc.** graphics line is being marketed now for use on the RT/PC. **Visual:GKS**, based on the graphics kernel system, is a subroutine library that allows systems programmers to take advantage of a predefined set of graphics capabilities. **Visual:C-Chart** is a presentation tool for developing business and scientific graphics applications. **Visual:ProChart** is a presentation quality charting system for the nonprogrammer. **Visual:GeniSys** is a library of 3-D rendering functions for applications in scientific and engineering analysis and simulation, architectural design, mechanical engineering, product design, facilities planning, and animation. All of these products use **Visual:GraphCap**, a knowledge-based management system that enables the RT/PC to support these graphics devices without software or hardware conversion. Visual:GKS, $695; Visual:C-Chart, $1,500; Visual:ProChart, $1,750; Visual:GeniSys, $8,000 to $12,000.
Visual Engineering, Inc., 2680 N. First Street, Suite 200, San Jose, CA 95134; 408/945-9055
CIRCLE 338 ON READER SERVICE CARD

Arity Corporation has announced five new artificial intelligence products that are fully integrated and preinterfaced. The **SQL Development Package** is a complete implementation of the SQL database language for use with Arity/Prolog to build intelligent database applications. The **Expert Systems Development Package** is an advanced expert system development tool that supports a frame-based knowledge representation as well as both rule and inheritance-oriented reasoning. The **Screen Design Toolkit** contains source and object code to allow the developer to design and lay out screens and procedures for building menus and windows. The **File Interchange Toolkit** gives programs written in Arity/Prolog the ability to read and write files written with other software, such as Lotus 1-2-3 or dBASE III. The **Standard Prolog** is a tutorial level Prolog product with introductory text. SQL Development Package, $295; Expert Systems Development Package, $295; Screen Design Toolkit, $49.95; File Interchange Toolkit, $49.95; Standard Prolog, $95.
Arity Corporation, 358 Baker Avenue, Concord, MA 01742; 617/371-1243
CIRCLE 333 ON READER SERVICE CARD

IntelliCorp has announced an agreement with IBM to port the **Knowledge Engineering Environment (KEE)** system to the IBM RT/PC. KEE enables users to develop and/or deliver original artificial intelligence applications, including expert systems.
IntelliCorp, 1975 El Camino Real W. Mountain View, CA 94040-2216; 415/965-5500
CIRCLE 337 ON READER SERVICE CARD

StruBAS provides structured programming facilities, full screen handling, indexed files, and menus. Introduced by **Laney Systems, Inc.**, this structured BASIC development system is designed to complement the BASIC compiler, BASICA, and Microsoft Quick BASIC. A preprocessor translates BASIC to Microsoft BASIC. Full cursor control, editing, field ordering, color control, and validation with rotation through values are supported. It features a utility that supports unlimited menu levels, a file maintenance program generator, development menus, an ISAM rebuild utility, a source indent utility, subroutines, and a sample application. $150.
Laney Systems, Inc., 3 Office Park Drive, Suite 105, Little Rock, AR 72211; 501/225-7755
CIRCLE 332 ON READER SERVICE CARD

OTHERWARE

Intel Corporation has released the **Product Guide**, a detailed overview of all products available from the company. This set of handbooks contains data sheets, applications notes, article reprints, and other design information and is intended to keep users up to date on the Intel product line. The series consists of ten books that can be purchased separately or as a complete set. Set of ten books, $120.
Intel Corporation, 3065 Bowers Avenue, Santa Clara, CA 95051; 800/548-4725; 408/987-8080
CIRCLE 340 ON READER SERVICE CARD

Erratum: In the hardware section of the March 1986 Tech Releases, the price of **Emerald Technology Group's** PC/5251 **MATE-48** should be $1,995.

The material that appears in Tech Releases is based on vendor-supplied information. These products have not been reviewed by the PC Tech Journal *editorial staff.*

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It can store mountains of information—literally thousands of pages' worth—with a single "hard file" (fixed disk). And now you can customize your system to store up to 30,000 pages with the addition of a *second* hard file.

The Personal Computer AT runs many of the thousands of programs written for the IBM PC family. Like IBM's TopView, the program that lets you run and "window" several other programs at once.

Perhaps best of all, it works well with both the IBM PC and PC/XT. Which is welcome news if you've already made an investment in computers.

You can connect a Personal Computer AT to the IBM PC Network, to share files, printers and other peripherals with other IBM PCs.

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If you'd like to learn more about the IBM Personal Computer AT, see your Authorized IBM PC Dealer, IBM Product Center or IBM marketing representative. For a store near you, call 1-800-447-4700 (in Alaska, call 1-800-447-0890).

The IBM Personal Computer AT, for Advanced Technology.

CIRCLE NO. 248 ON READER SERVICE CARD

TECH NOTEBOOK 63

MICHAEL ABRASH

Bit Rotation Speeds

When programming rotations in assembly language, the prefetch queue must be considered in order to optimize execution time.

Specifications for the 8088 state that the assembly language instruction ROL AX,1 (which rotates the AX register left one bit) executes in two cycles, while the instruction ROL AX,CL (which rotates AX left the number of bits specified in the CL register) requires four advance cycles to load CL, as well as the number of cycles determined by CL*4+8, to execute. Thus, rotation using the first method would seem more than twice as fast as using the second.

Surprisingly, when programming for the PC, this is not the case. Table 1 shows the execution times for the code in figure 1 when performing rotations of from 0 to 16 bits first with ROL AX,1, then with ROL AX,CL. The results indicate that for rotations of 5 to 16 bits, the method involving CL is faster. Only for rotations of fewer than 4 bits should ROL AX,1 be used. This is because, with the 8088, the fetch of the next instruction is not built into the instruction execution operation. Instead, a bus interface unit (BIU) reads instruction bytes into a four-byte prefetch queue. The BIU operates while the execution unit (EU) is carrying out the current instruction, using free memory in the prefetch queue as available. Instruction timing specifications are for the EU and assume that the instruction byte already has been fetched by the BIU.

Four clock cycles are required to read a byte from the PC's memory. With most instructions (especially those that access memory, because several cycles are required to calculate memory addresses), this works well and allows the BIU the memory access time it needs to keep up with the EU. The 8088, however, features instructions that operate only on the high-speed internal registers, which causes these instructions to execute extremely fast—faster than the BIU can fetch instruction bytes. ROL falls into this category of instructions.

ROL AX,1 executes in two cycles, but it requires four cycles to fetch the next instruction byte from memory. If the next instruction is another ROL AX,1, as in a multibit rotate, the instruction is two bytes long, and eight memory cycles are needed to fetch the next ROL. Thus, multibit rotates require eight cycles, not two, to rotate by one, because the EU must wait for the BIU to fetch the next instruction. ROL AX,CL, however, does require only the specified four cycles because once the instruction is fetched, it is executed repeatedly until the rotation is complete. Moreover, because memory is free during the execution of ROL AX,CL, the next four instruction bytes can be prefetched, then executed as soon as the rotation is complete. Thus, rotation by CL is preferable.

The method used to fetch instructions also can prove a bottleneck with other examples involving register-only operands. Any instruction that takes fewer than four cycles per instruction byte to execute depletes the prefetch queue.

Michael Abrash is a senior software engineer for Tseng Laboratories.

TABLE 1: *Rotation Benchmarks*

NUMBER OF ROTATIONS (N)	ROTATED BY CL COUNT=N	ROTATED N TIMES BY 1
0	165	97
1	173	129
2	193	165
3	217	192
4	231	231
5	247	270
6	265	289
7	289	337
8	289	371
9	309	404
10	324	433
11	347	474
12	361	505
13	372	541
14	385	577
15	408	609
16	423	645

Repeated use of ROL AX,1 depletes the prefetch queue and slows execution. ROL AX,CL takes longer to execute, giving the BIU time to refill the prefetch queue. Thus, ROL AX,CL is faster for rotates of four or more bits.

FIGURE 1: *Benchmark Code*

```
        SUB     CX,CX
        MOV     DX,CX
        MOV     AH,1
        INT     1AH     ; set clock to 0
        MOV     BX,10H  ; repeat rotate 10h*10000h
LP1:                    ; times for timing
        SUB     DX,DX
LP2:
; insert either rotate by cl or
; equivalent # of rotate by 1's
;******* EITHER *******
        MOV     CL,2    ; change cl for desired
        ROL     AX,CL   ; # OF ROTATES
;********* OR *********
        ROL     AX,1    ; insert desired # of
        ROL     AX,1    ; rotates by 1
;**** BUT NOT BOTH ****
        DEC     DX
        JNZ     LP2
        DEC     BX
        JNZ     LP1
        SUB     AH,AH
        INT     1AH     ; get clock ticks in CX:DX
```

This assembly language code fragment uses the system clock in order to time the ROL operator.

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Exclusive Special Offer from Programmer's Connection: Purchase a Lattice C compiler and receive a FREE copy of SecretDisk, Lattice's new file encryption and security package. Order soon, this offer expires on May 30, 1986.

	LIST	OURS
Lattice C Compiler (includes Free SecretDisk)	500	299
with Library Source Code	900	549

Popular, industry standard C compiler that features fast compilation, efficient code generation, support for 80186/286 instructions and inline support of 8087/287 instructions. The latest version now supports void, enum, unsigned as a modifier and function prototype checking. The library contains more than 325 functions compatible with UNIX, XENIX and the proposed ANSI standard, plus extensive support for MS-DOS versions 2.+ and 3.+. Other useful Lattice C features include support for nested comments, extended symbol length and multiple memory models. It comes with an object module disassembler, a function extract utility, a full set of libraries for each supported memory model, sample programs and extensive documentation. Requires 128K memory. **Exclusive special offer: purchase a Lattice C compiler and receive a FREE copy of Lattice SecretDisk. Offer expires on May 30, 1986.**

The C-Food Smorgasbord — Binary 150 / 99; with Source Code 300 / 195

General C function library featuring BCD (binary coded decimal) arithmetic, level 0 I/O, BIOS interface, terminal independence, directory, clock, string and other miscellaneous functions. No royalties. For use with Lattice C.

C-SPRITE — 175 / 139

Program debugger with source level support for Lattice C that includes help screens, macros, command files, conditional commands, debugging through a COM port and support for Plink86 overlays. The source mode supports all debugging functions including disassemble, single-step and breakpoints. The data types of symbols may be completely specified so that variables can be properly displayed. There is also complete assembly language support providing direct access to machine addresses and instructions. Requires 256K memory. Specify C compiler: Lattice or Microsoft.

Curses Screen Manager — Binary 125 / 99; with Source Code 250 / 199

Library of C screen interface functions compatible with curses packages on UNIX systems. You can keep and update any number of full or partial virtual screen images in memory and display them as needed. Functions are provided to write text to virtual screens, move the cursors, scroll the screens, overlay screens, outline, insert, delete, clear and highlight. No royalties. For use with Lattice C.

dBC II or dBC III — Binary 250 / 199; with Source Code 500 / 395

Complete C library of ISAM file management functions for creating and manipulating dBase compatible files. You can easily add, update, delete, retrieve and organize records and indexes in dBase format. Up to eight data and eight index files may be opened and processed simultaneously. Specify dBC II for dBase II type files or dBC III for dBase III type files. No royalties. Requires 128K memory. Specify C compiler: Lattice, Microsoft, Computer Innovations or DeSmet.

LMK Make Utility — 195 / 149

Programming utility to rebuild programs after changes have been made to source files. First, you create a text file consisting of macro definitions, dependency descriptions and executable commands. Then, whenever you make changes to your program, LMK determines which source files need to be recompiled and automatically creates the new program. Requires 128K memory and may be used with any compiler or assembler.

LSE Screen Editor — 125 / 99

Multi-window programmer's editor with block moves, pattern searching and "cut and paste." You can remap any of LSE's 48 keystrokes to suit your own preferences and define your own keyboard macros and default file extensions. The menus, prompts and help messages used in the system can all be customized. Special features include a Lattice C error tracking mode and three assembly language input modes. Requires 128K memory.

RPG II Compiler — 750 / 595

RPG II compiler for MS-DOS that is compatible with IBM System III, System/34 and System/36 RPG II compilers. Special PC extensions include support for standard MS-DOS files, keyboard, function keys and string handling. ISAM files are compatible with dBC III and dBase III files. Requires 192K memory.

SecretDisk — 60 / 49

File security utility for providing complete security for sensitive information on a floppy or hard disk system. You can use either the international Data Encryption Standard (DES) or Lattice's own Fast encryption algorithm for higher speed operation. It's loaded as a DOS device driver and creates new logical DOS drives where all files are fully encrypted. A password is entered when the system is booted and protection can be switched on and off with a single password controlled command line. Without the password, there is no known way to access the encrypted files! Multiple protected areas may be created using different passwords and data backup may be made in either encrypted or unencrypted mode. It does not interfere with normal access to the computer system or to files that are not encrypted. **Special Limited-time Offer: Purchase a copy of Lattice C and receive a FREE copy of SecretDisk! See description for Lattice C above.**

SideTalk — 120 / 95

Pop-up telecommunications package that can be accessed from inside any application with a single keystroke. It incorporates the SideTalk Communications Language (SCL) consisting of BASIC-like commands that allow you to create your own communications processing system. It provides for multitasking (background) operation, file transfer capabilities, text transfer from background to foreground and DOS commands available in background. Requires less than 64K available memory.

Text Management Utilities — 120 / 95

Includes four text management utilities found under UNIX. The first utility is grep (global regular expression search and print). You provide it with a pattern to find and it displays each line containing that pattern with its line number in that file. In addition, these functions are provided as Lattice C object libraries. The second utility is DIFF, a differential file comparator. It compares two files and determines how they differ from one another. The third utility is ED, a line editor and the fourth utility is WC, a simple word count facility for counting the number of characters, words and lines in a file. Requires 128K memory.

TopView Toolbasket — Binary 250 / 199; with Source Code 500 / 395

Library of C functions for simplifying programming in IBM's TopView environment. It gives you easy access to TopView's window, cursor, pointer facilities, cut-and-paste services and printer control services. It deals with TopView objects through a central dispatching function that can be tailored to your application. Includes excellent error checking and debugging support. Requires 256K memory (512K recommended). For use with Lattice C.

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apl language

	LIST	OURS
APL*PLUS/PC System by STSC	595	**449**
APL*PLUS/PC Tools Vol 1 by STSC	295	**239**
APL*PLUS/PC Tools Vol 2 by STSC	150	**129**
APL*PLUS/UNX System by STSC ... *For AT Xenix*	995	**795**
Btrieve *ISAM File Mgr* by SoftCraft ... *New version*	250	**195**
Financial/Statistical Library by STSC	275	**219**
FRESCO *Business Graphics System* by Mr. APL	300	**269**
Pocket APL by STSC	95	**79**
STATGRAPHICS by STSC	695	**539**

artificial intelligence

ExpertEASE by Human Edge ... *New*	695	**589**
ExpertEDGE by Human Edge ... *New*	795	**659**
Experteach by Intelliware ... *Complete System*	475	**389**
EXSYS *Expert System Development Software*	395	**339**
GCLISP *Golden Common LISP* by Gold Hill ... *All models*	CALL	**CALL**
Insight I by Level Five Research ... *AI Primer*	95	**75**
Insight II by Level Five Research	485	**389**
LISP by Microsoft ... *New Common Lisp*	250	**189**
Methods *Smalltalk-based Prototyping* by Digitalk	250	**209**
MicroProlog by Programming Logic Associates ... *New*	250	**219**
with APES	425	**369**
Professional MicroProlog by Programming Logic ... *New*	395	**349**
with APES	650	**569**
Prolog-86 from Solution Systems	125	**CALL**
Prolog-86 Plus from Solution Systems ... *New*	250	**CALL**
QNIAL by NIAL Systems ... *New*	375	**359**
Small-X by Kaplan	125	**99**
TransLISP from Solution Systems ... *New*	75	**CALL**
Turbo Prolog Compiler by Borland International ... *New*	100	**CALL**

assemblers and debuggers

8088 Assembler *w/Z-80 Translator* by 2500 AD	100	**89**
Advanced Trace-86 by Morgan ... *with ASM Interpreter*	175	**139**
Codesmith-86 *Debugger* by Visual Age	145	**109**
Cross Assemblers from 2500AD ... *Over 25 varieties*	CALL	**CALL**
Microsoft Macro Assembler with utilities	150	**99**
Periscope I *Debugger* by Data Base Decisions	295	**249**
Periscope II by Data Base Decisions	145	**115**
The PROFILER by DWB Associates ... *Includes source*	125	**95**
Turbo EDITASM *Fast Assembler* by Speedware	99	**84**
Visible Computer: 8088 by Software Masters	80	**65**

basic language

BetterBASIC by Summit Software ... *Now BASICA Compatible*	200	**165**
8087 Math Support	99	**85**
Btrieve Interface ... *Used with Btrieve*	99	**85**
C Interface ... *New*	CALL	**CALL**
Run-time Module	250	**225**
Microsoft QuickBASIC Compiler ... *BASICA Compatible*	99	**79**
Professional BASIC by Morgan	99	**79**
8087 Math Support	50	**47**
True Basic from Addison-Wesley	150	**105**
Run-time Module	500	**435**

blaise products

Asynch Manager *for C or Pascal*	175	**139**
C Tools	125	**105**
C Tools 2	100	**84**
Combination package ... *Special Price*	175	**149**
Exec *Program Chainer*	95	**79**
Pascal Tools	125	**105**
Pascal Tools 2	100	**84**
Turbo ASYNCH *for Turbo Pascal*	100	**84**
Turbo POWER TOOLS *for Turbo Pascal*	100	**84**
View Manager *for C or Pascal*	275	**209**
with Source Code ... *Special Price*	295	**239**

borland products

REFLEX *Data Base System* ... *New*	99	**75**
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Turbo EDITOR TOOLBOX	70	**54**
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Turbo LIGHTNING	99	**75**
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with 8087 or BCD	110	**77**
with 8087 & BCD	125	**84**
Turbo Prolog Compiler ... *New*	100	**CALL**
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c compilers

C-86 Compiler ... *See Computer Innovations Section*	395	**289**
Datalight C Compiler *with large memory model* ... *New*	99	**79**
DeSmet C Compiler *w/Source Debugger*	159	**145**
Eco-C *Complete Development System* by Ecosoft	125	**CALL**
Lattice C *with Free SecretDisk* ... *See Feature Page*	500	**299**
Let's C Compiler by Mark Williams	75	**69**
with csd Source Level Debugger	150	**129**
MWC-86 by Mark Williams ... *Special Price*	495	**289**
Microsoft C Compiler *with source debugger.* ... *New version*	495	**CALL**
Wizard C by Wizard Systems ... *Includes lint*	450	**369**

c interpreters

C-terp by Gimpel Software ... *Specify compiler interface*	300	**239**
Instant C by Rational Systems	500	**379**
Interactive C by IMPACC Associates ... *New*	249	**219**
Run/C from Lifeboat	150	**99**
Run/C Professional from Lifeboat	250	**189**

c utilities

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Application Programmer's Toolkit by Shaw American	395	**339**
BasicC Library by C Source	175	**135**
C Essentials by Essential Software ... *New*	100	**85**
C-lib by vance info systems	195	**125**
C Power Packs by Software Horizons	CALL	**CALL**
c-tree by FairCom ... *Includes source*	395	**329**
C Utility Library by Essential Software	185	**139**
C Windows by Syscom	100	**89**
C Wings by Syscom	50	**45**
dbVISTA *Single-User DBMS* by Raima	195	**159**
with Source Code	495	**429**
dbVISTA *Multi-User DBMS* by Raima	495	**429**
with Source Code	990	**849**
Entelekon C Function Library	130	**115**
Entelekon C Windows	130	**115**
Entelekon Superfonts for C	50	**45**
Entelekon Combination Package	200	**175**
Essential Graphics by Essential Software. *No royalties*	250	**219**
Flash-up Windows by Software Bottling of NY	75	**69**
GraphiC by Scientific Endeavors ... *Mono version 2.2*	280	**219**
GraphiC by Scientific Endeavors ... *Color version 3.0*	350	**299**
The Greenleaf Functions by Greenleaf Software	185	**135**
Greenleaf Comm Library by Greenleaf Software	185	**135**
The HAMMER by OES Systems	195	**175**
H.E.L.P. by Everest Solutions	90	**79**
MetaWINDOWS by Metagraphics	185	**139**
MetaWINDOWS/Plus by Metagraphics ... *New*	235	**199**
Multi-Halo by Media Cybernetics ... *Royalties*	300	**219**
On-line Help from Opt-Tech Data	149	**119**
PANEL by Roundhill ... *Library Source Available*	295	**229**
PC Lint by Gimpel Software	139	**109**
Scientific Subroutine Library for C by Peerless	175	**139**
Vitamin C by Creative Programming	150	**139**
VC Screen *Forms Designer* ... *Requires Vitamin C*	99	**85**
Windows for C by Vermont Creative Software	195	**139**
Windows for Data ... *Includes Windows for C*	295	**199**
Zview by Data Management Consultants	245	**199**

cobol language

Micro Focus COBOL Workbench	4000	**3599**
Micro Focus Level II COBOL	CALL	**CALL**
COMATH	200	**169**
FORMS-2	300	**269**
Level II Animator	1200	**995**
Level II FILESHARE	800	**659**
Level II SOURCEWRITER	2000	**1689**
Micro Focus Micro/SPF	175	**159**
Micro Focus Professional COBOL	3000	**2395**
Microsoft COBOL ... *See Microsoft Section*	700	**495**
Realia COBOL ... *New*	995	**795**
RM/COBOL by Ryan-McFarland	950	**675**
RM/COBOL 8X *ANSI 85 COBOL* by Ryan-McFarland ... *New*	1250	**995**

computer innovations products

C-86 Optimizing Compiler	395	**289**
C to dBase	150	**139**
CI Probe *Source Level Debugger*	225	**199**
CI ROM Pack *for C-86*	195	**149**
Introducing C ... *C Interpreter*	125	**105**

fortran language

ACS Time Series by Alpha Computer Service	495	**429**
Btrieve *ISAM File Mgr* ... *See SoftCraft Section*	-	**-**
For-Winds by Alpha Computer Service	90	**79**
Forlib-Plus by Alpha Computer Service	70	**55**
Microsoft Fortran ... *Links with Microsoft C*	350	**215**
MORE FORTRAN by Peerless Engineering ... *New*	125	**99**
Multi-Halo by Media Cybernetics ... *Royalties*	300	**219**
PANEL *Screen Designer* by Roundhill	295	**229**
PC Fortran Tools by Stat Com Systems ... *New*	179	**159**
PolyFortran Tools by Polytron	179	**139**
RM/Fortran by Ryan-McFarland	595	**395**
Scientific Subroutine Library by Peerless	175	**139**
Scientific Subroutine Package by Alpha Computer	295	**259**
The Statistician by Alpha Computer Service	295	**259**
Strings & Things by Alpha Computer Service	70	**55**

lattice products

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Lattice C Compiler .... *with Free Lattice SecretDisk*	500	299
with Library Source Code	900	549
C Cross Reference Generator	50	39
with Source Code .... *New*	200	159
C-Food Smorgasbord *Function Library*	150	99
with Source Code	300	195
C-Sprite *Source Level Debugger*	175	139
Curses *Screen Manager*	125	99
with Source Code	250	199
dBC *dBase File Manager for C*	250	199
with Source Code	500	395
LMK *Make Facility*	195	149
LSE *Screen Editor* .... *New*	125	99
RPG II Compiler	750	595
SecretDisk *File Security* .... *Free with Lattice C*	60	49
SideTalk *Resident Communications*	120	95
Text Mgmt Utilities *(GREP/DIFF/ED/WC/Extract/Build)*	120	95
TopView Toolbasket *Function Library*	250	199
with Source Code	500	395
Z-80 C Cross Compiler .... *New*	500	395
with Library Source Code	1000	789

microsoft products

	LIST	OURS
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Microsoft C Compiler *with source debugger.* ...... *New version*	495	CALL
Microsoft COBOL Compiler	700	495
Microsoft COBOL Compiler *for Xenix*	995	795
Microsoft COBOL Tools .... *with COBOL Source Debugger*	350	209
Microsoft COBOL Tools *for Xenix*	450	359
Microsoft Fortran Compiler .... *Links with Microsoft C*	350	209
Microsoft Fortran Compiler *for Xenix*	495	389
Microsoft LISP .... *New Common Lisp*	250	189
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Microsoft Mouse *Bus Version* .... *New*	175	149
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Microsoft muMath .... *Includes muSIMP*	300	195
Microsoft Pascal Compiler .... *Links with Microsoft C*	300	195
Microsoft Pascal Compiler *for Xenix*	495	389
Microsoft Sort	195	149
Microsoft QuickBASIC Compiler	99	79
Microsoft Windows	99	74

modula-2 language

	LIST	OURS
MODULA-2/86 Compiler by Logitech	89	65
with 8087	129	105
with 512K	189	149
MODULA-2 Editor by Logitech	59	49
MODULA-2 Runtime Debugger by Logitech	69	59
MODULA-2 Source Package by Logitech	179	155
MODULA-2 Utilities Package by Logitech	49	45

other products

	LIST	OURS
Dan Bricklin's Demo Program by Software Garden ... *New*	75	65
FASTBACK *Backup Utility* by 5th Generation Systems .. *New*	179	159
Interactive EASYFLOW by Haventree Software .... *New*	150	129
Janus/ADA C Pack by R&R Software	95	89
Janus/ADA D Pack by R&R Software	900	699
PC/Forth by Laboratory Microsystems	150	119
PC/Forth+ by Laboratory Microsystems	250	209

phoenix products

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Pasm86 *Macro Assembler*	295	179
Pfantasy Pac .... *Pfinish,Pfix+,Plink+,Pmaker,Pmate,Ptel*	1295	895
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Pfix-86 Plus *Symbolic Debugger*	395	229
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Plink-86 Plus *Overlay Linker*	495	359
Pmaker *Program Development Manager*	195	139
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Pre-C *Lint Utility*	395	229
Ptel *Binary File Transfer Program*	195	129

polytron products

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Polytron C Beautifier .... *New*	49	45
PolyFORTRAN Tools I	179	139
PolyLibrarian *Library Manager*	99	79
PolyLibrarian II *Library Manager*	149	119
PolyMake *UNIX-like Make Facility*	99	79
PolyOverlay *Overlay Optimizer*	99	79
Polytron PowerCom *Communications* .... *New*	179	139
PolyWindows Developer Kit .... *New*	199	149
PolyWindows Products .... *All varieties*	CALL	CALL
PolyXREF *Cross Reference Utility* .... *Complete system*	219	179
PolyXREF .... *Support for one language only*	129	109
PVCS *Polytron Version Control System*	395	359
PVMFM *Polytron Virtual Memory File Manager*	199	149

softcraft products

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Btrieve *ISAM File Mgr with no Royalties* .... *New version*	250	195
Btrieve/N *for Networks*	595	465
Rtrieve *Report Generator for Xtrieve*	85	79
Rtrieve/N *Report Generator for Xtrieve/N*	175	159
Xtrieve *Query Utility for Btrieve*	195	169
Xtrieve/N *Query Utility for Btrieve/N*	395	299
OPT-Tech Sort *Works with Btrieve Files* .... *New version*	149	119

text editors

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Brief *from Solution Systems*	195	CALL
Epsilon by Lugaru .... *New version*	195	165
FirsTime for Turbo by Spruce Technology	75	69
KEDIT by Mansfield Software Group .... *Like Xedit*	125	109
SPF/PC by Command Technology Corp	195	165
Vedit by CompuView	150	115
Vedit Plus by CompuView	125	180
XTC *Text Editor* by Wendin .... *Includes source*	99	84

turbo pascal utilities

Please refer to the following sections for additional products: Blaise, Borland and SoftCraft.

	LIST	OURS
ALICE by Software Channels .... *New Pascal Interpreter*	95	85
FirsTime for Turbo by Spruce Technology	75	69
Flash-up Windows by Software Bottling of NY	75	69
Multi-Halo *Graphics* by Media Cybernetics .... *Royalties*	250	CALL
On-line Help from Opt-Tech Data	149	119
Screen Sculptor by Software Bottling of NY	125	95
Turbo EXTENDER by TurboPower Software .... *New*	85	69
Turbo Professional by Sunny Hill Software	70	49
TurboRef by Gracon Services	50	45
TurboPower Utilities by TurboPower Software	95	84
TurboWINDOW by MetaGraphics	80	69
XTC *Text Editor* by Wendin	99	84

video training tapes

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Local Area Networks .... *New*	350	CALL
Programmer's Introduction to C .... *New*	500	CALL

wendin products

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PCVMS *Operating System* .... *Similar to VAX/VMS*	99	84
XTC *Text Editor* .... *Includes Pascal source code*	99	84

xenix system v by sco

	LIST	OURS
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Xenix Operating System .... *Specify XT or AT*	495	449
Xenix Text Processing Package .... *Specify XT or AT*	195	179
Complete Xenix System .... *Specify XT or AT*	1085	969

xenix languages and utilities

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APL*PLUS/UNX System by STSC .... *For AT Xenix*	995	795
Btrieve *ISAM File Manager* by SoftCraft	595	465
c-tree by FairCom .... *Includes C source code*	395	329
Informix by SCO	995	839
Lyrix by SCO	595	489
Microsoft Languages .... *See Microsoft Section*	-	-
Networks for XENIX by SCO .... *New*	CALL	CALL
PANEL *Screen Designer* by Roundhill .... *For AT Xenix*	595	539
SCO Professional by SCO .... *Complete Lotus clone*	795	695
Windows for C by Vermont Creative Software	395	359
Windows for Data by Vermont Creative Software	595	539

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programmer's connection

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Digitizing Analog Data

Data acquisition boards from seven manufacturers are examined from a hardware point of view. Their specific performance characteristics help a user select a suitable board for a given application.

ERIC M. MILLER

Data acquisition boards occupy an unusual niche in personal computer applications. They bridge the gap between the software world and the physical world of continuous data. It is this interface to the real world, rather than the programming of these cards, that is the focus here. Although the software is important in reducing the time to bring a card up and accomplish a given task, no amount of clever programming can make up for fundamental analog hardware instrumentation errors and defects.

The cards reviewed are not test and measurement grade instruments—they provide only a foundation for measurement. The user must add circuitry to accurately and nonintrusively accomplish monitoring and control functions. Also note that although a wide range of data acquisition systems exist that reside in external boxes, this review covers only internal products. The companies represented are Burr-Brown, Data Translation, IBM, Metra-Byte Corporation, Scientific Solutions, Strawberry Tree Computers, and Western Telecomputing, each with one or more boards. (See table 1 for a summary of the products reviewed and their basic features.) None of the manufacturers provided sufficient information to determine the accuracy of its data acquisition card for an application, nor did any offer guidance for determining a system's overall accuracy.

The standard architecture for a typical data acquisition board is shown in figure 1. The analog input signals are sent through to the analog-to-digital (A/D) converter via conditioning circuits that permit the collected data to be output as required. After some precautions involving grounding, attention is turned to the analog input channel, then the remainder of the I/O.

Grounding considerations for instrumentation work are an important aspect in the design of any system. Normally, the analog ground for the measurement system is isolated from the power-line ground; however, none of the boards reviewed did so. All of their analog and digital I/O grounds are connected to each other and to the power line ground inside the PC. Thus, the user must exercise considerable caution in interfacing to apparatus or sensors that also may have a power-line ground connection in order to prevent any hazards or ground loop currents.

It is not unusual, especially with heavy current consumption devices (motors, ovens, etc.) operating from the power line, to have a substantial potential difference, on the order of volts, across two power-line receptacles. Misapplication obviously could seriously damage all the attached equipment.

Differential inputs should be used unless a sensor is completely isolated from any power-line ground to avoid ground-related problems. Even so, the analog ground must be connected to stay within the input differential common mode limits. (More information on this is available in the references listed at the end of this article.)

Input protection. The first stage of the data acquisition board should be the

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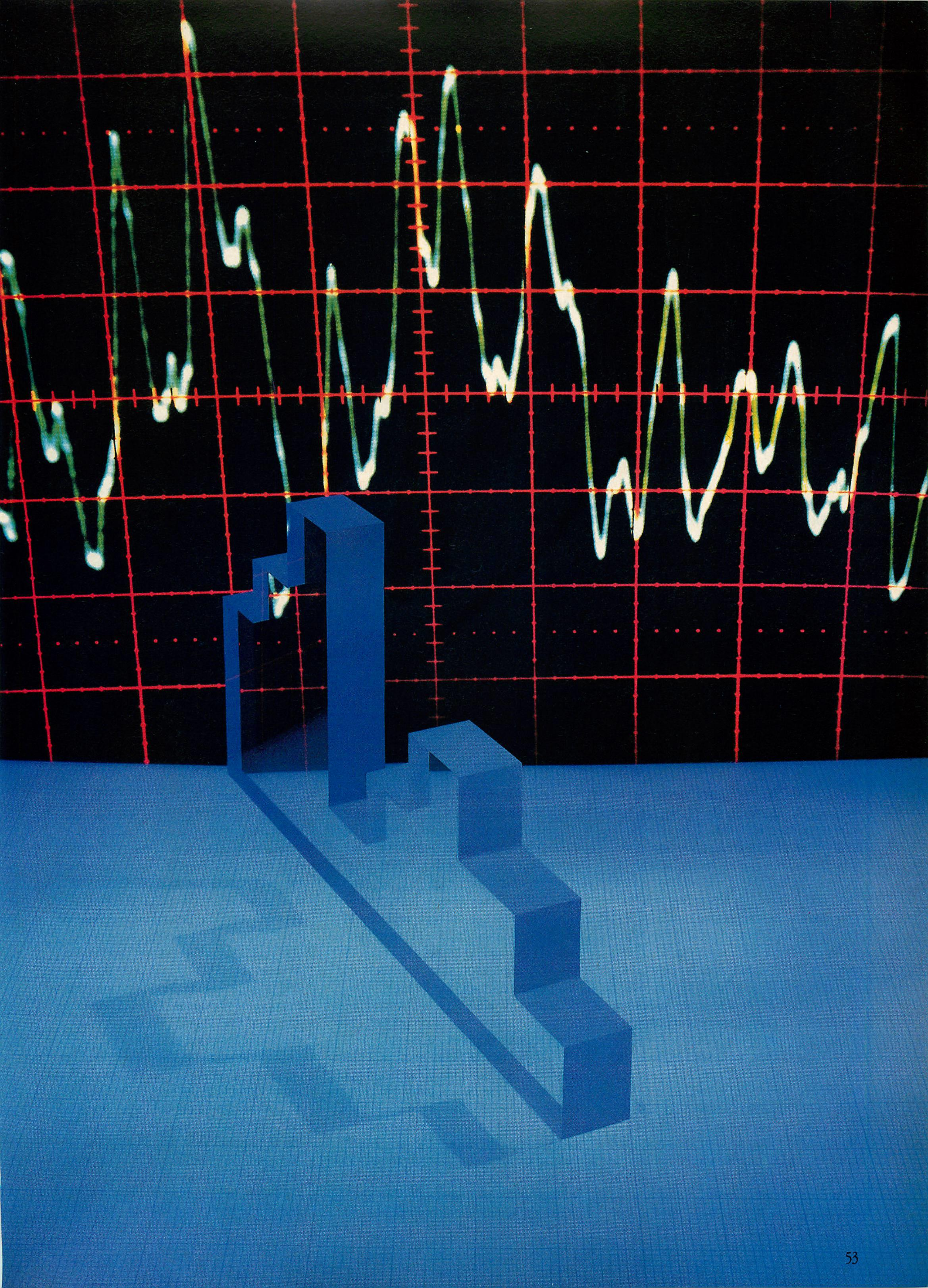


TABLE 1: *Summary of Basic Features*

	BURR-BROWN 20001 C-2	20002	20019	20003	20006	DATA TRANS. DT2801-A
A/D CHARACTERISTICS						
A/D type[a]	N/A	2	2	N/A	N/A	2
Resolution (bits)	N/A	12	12	N/A	N/A	12
Accuracy (bits)	N/A	N/S	N/S	N/A	N/A	0.05% overall
Speed (conv./sec)	N/A	25,000	87,000	N/A	N/A	27,500
No. of channels						
Differential	N/A	8	None	N/A	N/A	8
Single-ended	N/A	16	8	N/A	N/A	16
Input ranges (volts)	N/A	+/−5, +/−10 0 to 10 Gains = 1, 10 100, 1,000	+/−2.5, +/−5, +/−10, 0 to 5, 0 to 10	N/A	N/A	+/−1.25, +/−2.5, +/−5, +/−10, +1.25, +2.5 +5, +10
D/A CHARACTERISTICS						
No. of D/A on board	N/A	N/A	N/A	2	2	2
Resolution	N/A	N/A	N/A	12-bit	16-bit	12
Range (volts)	N/A	N/A	N/A	+/−5, +/−10 0 to 10	+/−5, +/−10 0 to 10	+/−2.5, +/−5, +/−10, +5, +10
Number of parallel I/O channels	32	None	None	None	None	16
TIMER/COUNTER CHARACTERISTICS						
Type	None	None	None	None	None	Int. only
No. of channels	N/A	N/A	N/A	N/A	N/A	N/A
No. of bits	N/A	N/A	N/A	N/A	N/A	N/A
Realtime clock	None	None	None	None	None	None
Terminal box[f]	N/A	C	C	C	C	D (on PCB)
Supports ASYST	Yes	N/A	N/A	N/A	N/A	Yes
Supp. Lab Tech Note.	Yes	N/A	N/A	N/A	N/A	Yes
Other	Motherbd.	Module	Module	Module	Module	On-board 8742

N/A = Not applicable; N/S = Not supplied.
[a]Type 1 = integration; type 2= successive approximation.
[b]Can be used for voltage or frequency.
[c]16 output (28 LSTTL loads), 16 input (LSTTL)
[d]32-bit, 1.023 MHz input; 16-bit, DC-2 MHz input.
[e]100 KHz input may be used for voltage or frequency.
[f]Type A = plastic box with mini-screw clamp connectors.
Type B = ribbon cable headers.
Type C = printed circuit board with mini-screw clamp connectors.
Type D = barrier terminal strip.
Type E = with thermocouple compensation.
[g]Unshielded cable, screw terminals.
[h]19-inch rack mount.

input protection circuitry. Accidents *do* happen, so attention should be given to this important element. This is especially true in industrial environments where sensors can cross paths with power circuits. Most manufacturers of data acquisition boards rely solely on the small measure of protection offered by the multiplexer (typically the Harris 508A or 506A). It can withstand continuous ± 20 V (volts) over its power supply voltages. (The typical supply voltage used is ± 15 V). It also gives superior electrostatic discharge protection, up to 5 or 6 KV (kilovolts).

Three of the reviewed boards did offer external protection: IBM protects to ± 30 V, Strawberry Tree to ± 50 V, and the MetraByte DASCON 1 to 120 V RMS (root mean square) continuous.

Multiplexers. This next input stage presents an analog channel to the subsequent signal processing circuitry. Ideally, a multiplexer should look like a straight piece of wire between the output and the chosen input. These devices can exhibit extremes in performance.

Multiplexers can produce temperature-dependent offset voltages in the microvolt range, but this affects only those systems with high gain (greater than 1,000). They have a nasty habit of dumping leakage current, typically in the 100-pA (picoampere) range, into (or out of) the analog input. However, if the PC's expansion slots are filled, the temperature inside the box can rise dramatically, with a resultant increase in leakage current—the amount can double every 10 degrees centigrade.

These devices also present a changing capacitive load on an analog input line when they switch from the on condition to the off. This charge-injection effect dumps (or extracts) a packet of charge onto the input. Up to 150 pC (picocoulombs) of charge can suddenly appear on the input, which causes a voltage spike of magnitude $V = Q/C$ (C is the capacitance on the input line).

For example, if an input line has a low 50 pF (picofarads) of capacitance associated with it, a 150-pC charge dump will cause a 3-V spike. The spike will decay, the time constant for which depends upon the source resistance. If it is low—less than 1 KΩ (kilohm)—no problems result, because the spike will have disappeared before the sample-and-hold grabs the voltage. But, if the source resistance is high, the sample-and-hold grabs the input voltage plus a fraction of the spike. The user must be aware of the source resistance, input channel capacitance, and charge injection to be sure the sample-and-hold is triggered after the spike has decayed to an acceptable level.

Although often not explicit in data sheet or manual, the specifications for the data acquisition boards assume a zero input impedance. The user must calculate the errors produced by the application's nonzero input impedance and apply them to the system accuracy.

IBM BOARD	METRABYTE DASCON 1	DASH 8	DASH 16	SCIEN. SOL. LAB MASTER	STRAWBERRY TREE ACPC-14-16	ACPC-16-16	WEST.TEL. ICIS
2	1	2	2	2	1	1	1
12	12 + sign	12	12	12	14	16	12
N/S	0.01% +/−1 bit	0.01% +/−1 bit	0.01% +/−1 bit	+/−0.025%	11	11	12
15,000	30	30,000	35,000	30,000	2.5 (variable)	200	10
4	4	None	8	8	16	16	16[b]
None	None	8	16	16	None	None	None
0 to 10, +/−5, +/−10	+/−2.0475	+/−5	0 to 1, 0 to 2, 0 to 5, 0 to 10, +/−0.5. +/−1, +/−2.5, +/−5, +/−10	0 to 10, +/−10	0.05, 0.5, 10, +/−0.025, +/−0.25, +/−5	0.05, 0.5, 10, +/−0.025, +/−0.25, +/−5	+/−0.01, +/−0.1 +/−1, +/−10
2	2	None	2	2	2	None	8
12-bit	12	N/A	12-bit mult.	12-bit	8-bit	N/A	12-bit (opt.)
0 to 10, +/−5, +/−10	N/S	N/A	N/S	N/S	N/S	N/A	+/−10
16[c]	12	7	8	24	16	16	24
Two[d]	None	8253-5	8253-5	9513	None	None	82C53
1 per timer	N/A	3	3	5	N/A	N/A	16
32, 16	N/A	16	16	16	N/A	N/A	—[e]
None	1	None	None	None	1	1	1 in software
D (shielded)	A	A	A	B	E[g]	E[g]	D[h]
Yes	No	No	Yes	Yes	No	No	No
Yes	No	Yes	Yes	Yes	No	No	No
I/O mapped only	N/A	Half-card	N/A	Input expans. (14, 16-bit), I/O or memory mapped	Expansion by adding cards	Expansion by adding cards	On-board 80C85, opt. battery

A wide range of data acquisition boards is available for different applications. Applications requiring conversion rates from 2.5 to 87,000 conversions per second can be accommodated. A variety in the number and type of input channels is offered.

Multiplexer isolation between channels at DC (direct current) to 1 KHz (kilohertz) is high—typically greater than 100 dB (decibels)—but this deteriorates rapidly as the frequency of the signal increases. The isolation also depends upon the impedance seen by the on channel. The user need not worry if all inputs are driven by low impedance sources. He should be cautious if an application requires digitizing not only high-level signals in the tens of kilohertz range, but low-level signals as well. The feed-through from the deselected high-level signal can cause significant errors in the low-level reading. Good practice indicates that all unused analog channels are terminated to analog ground.

The Harris 508A is used on many of the reviewed boards (table 2 lists the significant components used). It is a particularly good choice, but by no means perfect. Its strength is that in the face of overvoltages and static discharge it comes through like a trooper. A second nice feature of the 508A is that if a deselected channel experiences an overvoltage condition, it does not affect the present on channel.

An input multiplexer is not used in some applications. To achieve this and yet preserve the time relationship between various analog inputs, some boards use a *sample-and-hold* amplifier for each channel desired. The sample-and-holds are strobed simultaneously. A back-end multiplexer then allows the A/D conversion to occur sequentially to complete the data acquisition. None of the reviewed boards were designed for this configuration, although it is possible to use some of the Burr-Brown modules as a back-end multiplexer.

Instrumentation amplifier. An IA performs two functions: it converts a differential input to a single-ended output, and it supplies gain. In most situations, the IA input specifications determine the input characteristics of the data acquisition board. Its voltage offset and offset voltage drift contribute directly to the overall offset specification. Its input bias current (and bias current offset) often limit the maximum source resistance for the application. The common mode rejection ratio (CMRR) is also an offset-producing phenomenon. Theoretically, if the plus and minus inputs of an IA are tied together and raised a volt, no change should be evident in the output. In reality, the IA will convert that common mode signal to an input offset, and amplify it by its gain. A 60-dB CMRR means that the IA will develop a 1-mV (millivolt) input voltage offset when both inputs are raised 1 V. CMRR will decrease with frequency (starting at about 10 Hz) at a rate of approximately 20 dB per decade. The higher the CMRR, the better chance the data acquisition board has of combating common mode and ground induced noise.

For low sampling rates, the AC (alternating current) performance of the

TABLE 2: *Summary of Significant Components Used*

	BURR-BROWN 20002	20019	20003	20006	20017	DATA TRANS. DT-2801-A
INPUT STAGES						
Input circuitry protection	None	None	N/A	N/A	None	None
Multiplexer type	BB MPC8S[b]	BB MPC8S[b]	N/A	N/A	None	Harris 508A
Instrumentation amplifier type	Burr-Brown PGA-200AG	None	N/A	N/A	Burr-Brown INA 102AG	3 PMI-OP-15
Sample-and-hold type	National LF389A	Teledyne TP4866	N/A	N/A	National LF398A	National LF398A
Sample-and-hold capacitor (pF)	1,000	100	N/A	N/A	1,000	1,000
A/D type	Harris 574KD	Burr-Brown ADC84KG	N/A	N/A	N/A	AMD2504, LT311, AD565
A/D reference	On 574KD	On ACD84KG	N/A	N/A	N/A	On D/A Con.
Input amplifier type[c]	S and D	S	N/A	N/A	D	S and D
OUTPUT STAGES						
D/A converter type	N/A	N/A	Burr-Brown DAC11A	Burr-Brown DAC709K	N/A	AD7545LN
Output amplifier type	N/A	N/A	On DAC811A	On DAC709K	N/A	LM258

[a]*Series resistor with diode clamp.* [b]*Harris 508A look-alike.* [c]*S = single-ended; D = differential.*

IA can be neglected. For sampling rates in excess of a few hundred hertz, however, the AC limitations can play an often unexpected role.

Foremost is the brick-wall limitation of slew rate. The output of the IA cannot traverse a signal step faster than it can slew. Assuming a simple sine wave input, the slew rate for the signal is given by the equation

$$\text{slew rate} = 2\pi\, FVpp$$

where F is the sine's frequency and Vpp is the peak-to-peak voltage. Suppose that the IA on a data acquisition board can slew at 0.5 volts per microsecond and the user needs to determine the highest frequency sine wave that he can digitize, yet make maximum use of the A/D full-scale range (± 10 V). In this case, the frequency would be:

$$F = \frac{\text{slew rate}}{2\pi\ \text{Vpp}} = 3.978\ \text{KHz}$$

Signal frequencies higher than this will be greatly distorted and erroneous measurements will result.

The next fundamental limitation is that of finite bandwidth, which can cause two measurement errors. The first limitation is the response time of the IA to a change in the input signal. Assuming a first order system, the time that it will take for the output to settle within a specified error is given by

$$t = \frac{-\ln(\text{err})}{2\pi\ \text{Fo}}$$

where *err* is the error and *Fo* is the -3-dB bandwidth of the IA at the gain of interest. Suppose that the IA has a -3-dB bandwidth of 10 KHz at a gain of 100. The time it will take the IA to settle to within 1 LSB (least significant bit) for a 12-bit converter will be:

$$t = \frac{-\ln(1/2^{12})}{2\pi\ 10^3} = \frac{-\ln(2.4 \times 10^{-5})}{2\pi\ 10^3}$$

$$= 169\ \text{microseconds}$$

As gain increases, IA bandwidth decreases, and longer acquisition times will be necessary. Sampling before the IA has settled can result in significant errors.

The second bandwidth limitation effect is even more insidious. Remember that a -3-dB bandwidth frequency is the frequency at which the IA gain is 30 percent down from its DC gain. This decrease in gain begins far before the -3-dB point and can materially affect surprisingly low frequency measurements. Reconsider the IA example above, with the gain of 100 and the -3-dB point at 10 KHz. Suppose the user wants to digitize the highest frequency signal he can, yet retain 1 LSB (at 12 bits) amplitude accuracy after the A/D stage. The maximum frequency at which the data acquisition board would be able to do this is 221 Hz; although the arithmetic is straightforward, table 3 shows results from similar calculations.

This simplified analysis using only first order behavior is negated by certain components that also demonstrate some second order frequency responses. The Precision Monolithics, Inc. (PMI) AMP-01, as it is used by MetraByte, has a nasty peak in its frequency response at low gains that makes accurate use past a few kilohertz impossible.

An anti-aliasing filter should be present at this point; however, none of these boards takes this precaution. Aliasing occurs when a signal is sampled at a rate less than twice the signal's frequency (this sampling rate limit is called the Nyquist rate). This error causes a high-frequency input signal, after conversion, to appear to the CPU at the output as a lower frequency signal. The user must take care that signals with a significant frequency content that is above one-half of the sampling rate not get through to the remainder of the system. An anti-aliasing filter at this position in the circuit averts the problem.

Sample-and-hold amplifier. Most data acquisition boards use *successive approximation* A/D converters for speed and versatility, making necessary a sample-and-hold amplifier. The successive approximation converter requires that the input voltage remain constant throughout conversion. The sample-and-hold acquisition time adds to the overall conversion throughput time directly. Sample-and-hold accuracy also depends upon the input signal slew rate. The manufacturers' data sheets provide graphs that show the possible error for sample frequencies.

In systems without an instrumentation amplifier, the input characteristics of the sample-and-hold dominate the overall system input specifications.

Analog-to-digital. The A/D converter is the last stop for the input analog volt-

IBM BOARD	METRABYTE DASCON 1	DASH 8	DASH 16	SCIEN. SOL. LAB MASTER	STRAWBERRY TREE ACPC-14-16	ACPC-16-16	WEST. TEL. ICIS
+/−30 V[a]	+/−120 V RMS[a]	None	None	None	+/−50 V[a]	+/−50 V[a]	None
AD7502K	CD4052	Harris 508A	Harris 508A	Harris 508A	CD4052	CD4052	Harris 506A
S/H TL064	Opt. LM363D	None	PMI AMP-01	3 PMI-OP-15	LM308	LM308	AD524AD
Analog Dev. AD583KD	N/A	LF398	LF398	LF398A	N/A	N/A	N/A
2,200	N/A	4,700	2,200	1,000	N/A	N/A	N/A
AD674AKD	Teledyne 7109	Harris 574AJD	Harris 674AJD	AMD2504, LT311, AD565	LM331	LM331	ADVF32KN
On 574AKD	LM329BZ	On 574AJD	On 574AJD	On D/A Con.	LM399	LM399	AD584JH
D	D	S	S and D	S and D	D	D	D
AD7545KN	ADDAC80N CBI-V	N/A	AD7548KN	ADDAC80Z CBI-V	DAC0800LN	N/A	AD390JD
AD644KH	On ADDAC80N	N/A	OP-07D	On ADDAC80Z	LM324	N/A	On AD390JD

The reference for the A/D converter is obtained from different components. Some boards use the reference available from the A/D circuitry; others use an industry standard such as an LM399. The input protection on these boards is not really sufficient.

age signal. The successive approximation A/Ds usually are packaged in a single 24- or 28-pin DIP and are monolithic or hybrid in construction. Most incorporate the successive approximation register, D/A converter, voltage reference, comparator, and interface circuitry in the same package.

A sample-and-hold amplifier, followed by a successive approximation A/D converter, is very susceptible to noise. When confronted with it, these devices perform poorly, randomly sampling and converting the peaks and valleys of the noisy signal. Software can smooth the output data somewhat.

The *integrating A/D* converter is an alternative to successive approximation. Although slower, this A/D provides superior noise rejection and, in many cases, higher resolution. It is the A/D of choice, particularly in applications requiring high sensitivity—less than 100 mV (millivolts) full scale. MetraByte, Strawberry Tree, and Western Telecomputing offer boards that feature integrating A/D converters.

Reference. The *reference* sets the overall channel accuracy and stability for the A/D. Its time and temperature drift affect accuracy directly. Some boards use the reference available in the A/D converter itself. Others use off-the-shelf references, such as National's LM399. Strawberry Tree is the only manufacturer to specify time-related drift.

Bus control and interface. Data may be obtained from the analog conversion channel by polling the A/D converter until a conversion-complete signal has been received, then having the CPU read the data. Note that in the IBM PC, reading the data requires a minimum of two fetches for A/D resolutions greater than eight bits. Interrupts are sometimes used to signal the CPU that the A/D has valid data. The fastest method of obtainment is to use a DMA channel to grab the data directly from the data acquisition card and put it appropriately in memory. This, of course, requires the least amount of time from the CPU.

Analog output. An *analog output channel* consists of a reference, a D/A (digital-to-analog) converter, and an output amplifier. Some companies combine all three components into one package—for example, the industry workhorse, output voltage Analog Devices DAC80. The typical ranges are ±5 V, ±10 V, and 0 to +10 V. Output current is limited to 5 mA (milliamperes).

None of these boards supplies output protection other than short circuit current limit. The D/A converter will be destroyed if the output comes into contact with, for example, an external 18-V power supply. The IBM and Data Translation boards provide the proper compensation around their output amplifiers to tolerate up to 0.5-microfarad capacitive loads. The D/A converters on most other boards will oscillate with a few thousand picofarads of load capacitance, especially when forcing negative voltages. Even a few hundred picofarads of capacitance can cause ringing, and the attendant long settling times that this can produce.

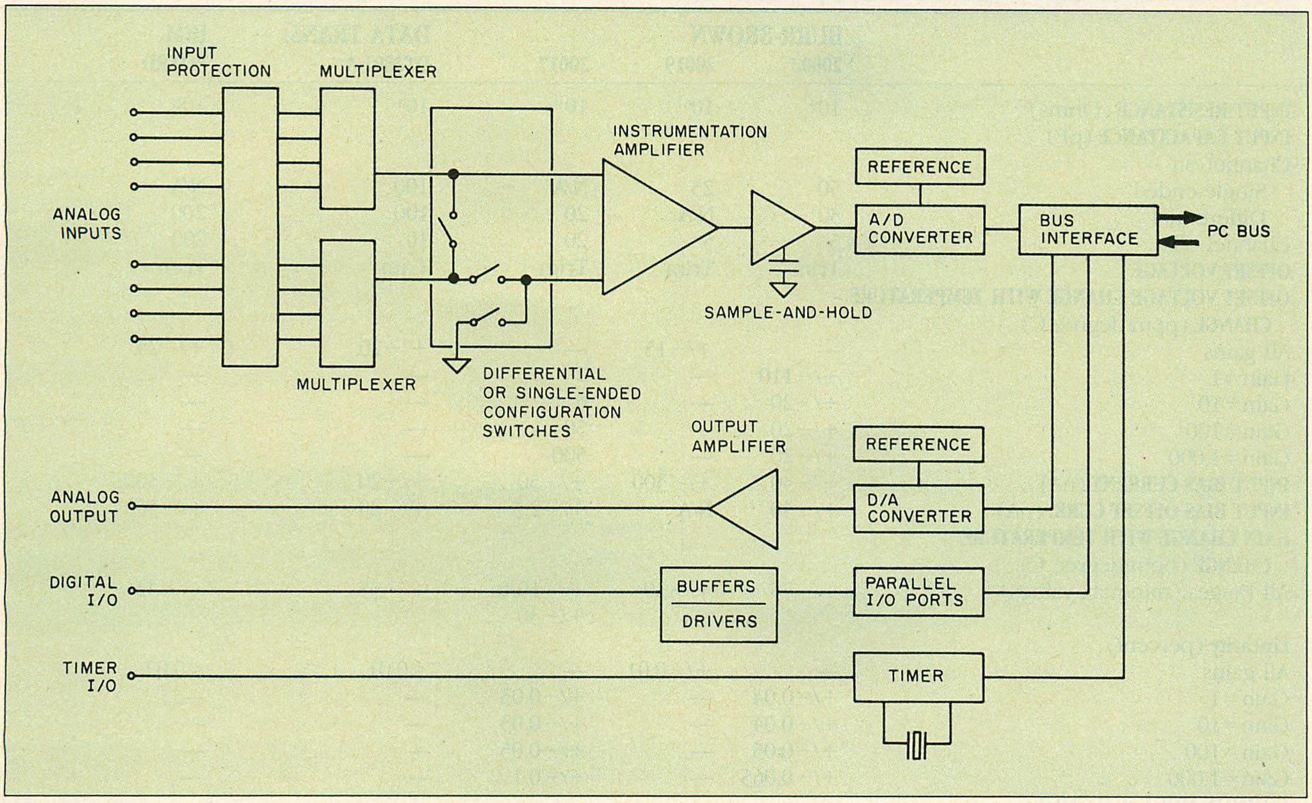
Shielding the D/A converter outputs is just as important as shielding the analog inputs. Although the D/A converter output resistance is low at DC (usually in the range of 0.1 ohms or less), the output impedance increases by a factor of 10 for each decade of frequency above 10 Hz. The D/A converter is powerless against interference from RF (radio frequency) sources, which is more common than users might suspect. Typically the RF comes down the unshielded D/A converter output and into its amplifier. It is rectified by nonlinearities in the input stage and ap-

TABLE 3: *Maintaining Signal Accuracy*

Required accuracy	1%	1LSB	1LSB	1LSB	1LSB	1LSB
Resolution of A/D (in bits)	any	8	10	12	14	16
−3dB ratio	7.0	11.3	22.6	45.2	90.5	181.0
1/−3dB ratio	0.143	0.088	0.044	0.022	0.011	0.006

The decrease in gain of the Instrumentation Amplifier occurs before the −3-dB point. This effect should be considered to ensure that signal fidelity is maintained throughout the system. As an example of reading this table, to maintain frequency fidelity within one percent of the maximum, frequency should be no greater than 14.3 percent of the instrumentation amplifier's −3-dB gain point.

FIGURE 1: *Block Diagram of a Typical Data Acquisition System*



The design of each stage of the board has a significant effect on its overall performance. The reviewed boards did not supply all aspects of this ideal situation. For example, the conversion time off the S/H contributes directly to the total throughput.

pears as a spurious DC offset voltage. The D/A converter output changes as a result of this phenomenon, and may be hundreds of millivolts away from what the user has programmed. It even may change in relation to the user's proximity to the output (because of resultant changes in the RF field).

Parallel and timer I/O channels. Parallel I/O is usually limited to the industry-standard 8255, or a couple of TTL (transistor-to-transistor logic) latches. Many manufacturers supply termination boards with optoisolated conversion for AC voltage sense and control, or relays for digital control of user-supplied sense and control circuitry.

Timers are most often of the 8253 type: three 16-bit counter/timers in a package. They are typically used for timing A/D conversions, for the counting of external inputs, or for the generation of pulse widths. A realtime clock is of marginal use, excepting those applications that require unattended operation.

Several boards have their I/O connectors (both analog and digital) sprinkled across them. It is quite a task to connect the multiplicity of cables and thread them. When the cables are connected and threaded through the cable opening, many invectives are generated. More importantly, stringing unshielded digital I/O cables across the top of sensitive analog circuitry is asking for trouble. The better data acquisition boards (IBM, Data Translation, MetraByte) have a single connector at the proper end. The user simply installs the board and hooks up his cable.

The cable or cables also contribute to the characteristics of the analog I/O. Unshielded ribbon cable adds approximately 14 pF per foot of capacitance to the I/O line, shielded cable about 25 pF per foot. The user must be aware of the length of the I/O cables and of the added capacitive load they provide.

A final consideration regarding I/O cables applies to all of the boards except IBM's: when the user connects the I/O cables to the data acquisition board, he nullifies precautions the PC manufacturer took to keep RFI (radio frequency interference) and EMI (electromagnetic interference) inside its covers. For example, if he hooks up three-foot I/O cables, the PC becomes a broadband radio station with a three-foot antenna. The user must be aware of relevant FCC regulations and take appropriate measures to curb interference.

Calibration. The user should calibrate the data acquisition board upon its arrival. Another calibration should take place after one month, then yearly. The bulk of time-related drift occurs within the first 1,000 hours. Calibration usually requires equipment unavailable to the average user. For 12-bit systems, a DC voltage calibrator with overall accuracy better than 60 ppm (parts per million) is mandatory. This, used in conjunction with a 5½-digit DVM (digital volt meter), should be sufficient.

Many of the boards will require recalibration should the A/D or D/A ranges be changed or the instrumentation amplifier gain altered. A prudent measure for any set-up is to dedicate two of the analog input channels for autozero and autocalibration. Software then can provide the necessary correction. The autozero channel simply connects to analog ground, thereby measuring the channel offset. The autocalibration channel connects to a known reference (a user could design his own based on an aged LM399 from National) for calculating the overall channel gain. Both time- and temperature-related accuracy dependencies can be corrected using this technique.

Software. Three software-related items should be available with each board. First, the instructions should show how

TABLE 4: *Summary of Electrical Characteristics*

	BURR-BROWN 20002	20019	20017	DATA TRANS. DT2801-A	IBM BOARD
INPUT RESISTANCE (Ohms)	10^9	10^6	10^{10}	10^8	10^8
INPUT CAPACITANCE (pF)					
Channel on					
Single-ended	50	25	N/A	100	N/A
Differential	30	N/A	20	100	200
Channel off	5	5	20	10	200
OFFSET VOLTAGE	Trim	Trim	Trim	Trim	Trim
OFFSET VOLTAGE CHANGE WITH TEMPERATURE CHANGE (ppm/degree C)					
All gains	—	+/−15	—	+/−20	+/−24
Gain=1	+/−110	—	2	—	—
Gain=10	+/−20	—	6	—	—
Gain=100	+/−20	—	50	—	—
Gain=1,000	+/−20	—	500	—	—
INPUT BIAS CURRENT (nA)	+/−30	+/−300	+/−50	+/−20	+/−300
INPUT BIAS OFFSET CURR. (nA)	+/−30	N/A	+/−2.5	+/−20	+/−300
GAIN CHANGE WITH TEMPERATURE CHANGE (ppm/degree C)					
All ranges (min/max values)	+/−75	+/−30	+/−10 to +/−30	+/−35	+/−32
Linearity (percent)					
All gains	—	+/−0.01	—	<0.01	<0.02
Gain=1	+/−0.04	—	+/−0.03	—	—
Gain=10	+/−0.04	—	+/−0.03	—	—
Gain=100	+/−0.05	—	+/−0.05	—	—
Gain=1,000	+/−0.065	—	+/−0.1	—	—
COMMON MODE REJECTION RATIO (DC) (dB)					
All gains (min/max value)	80/106	N/A	70/90	80	72
CHARGE INJECTION (pC)	10	10	N/A	10	150

[a]When 50-mV channel selected. 10^9 Ohms.
[b]Isolated from inputs by 100-KΩ resistors.
[c]Except 50-mV range, when it is +/−10 ppmm/degree centigrade.
[d]Effects swamped by 0.01-microfarad capacitor at input.

TABLE 5: *Summary of Digital-to-Analog Characteristics*

	BURR-BROWN 20003	20006	DATA TRANS. DT2801-A	IBM BOARD
ACCURACY	Trim	Trim	Trim	Trim
RESOLUTION	12	16	12	12
FAULT PROTECTION	No	No	No	No
MAX. LOAD CAPAC. (nF)	0.5	0.5	500	500
OFFSET DRIFT WITH TEMP. (ppm/degree C)	+/−60	+/−10	+/−30	+/−24
GAIN DRIFT WITH TEMP. (ppm/degree C)	+/−80	+/−25	+/−30	+/−35

[a]Maximum variation is within the overall accuracy specification of 10 percent.

to interface to the board at the lowest software level; that is, all of the ports the board uses for control and I/O should be discussed thoroughly, and examples should be provided.

Second, software drivers that provide functions for access by a reasonable number of high-level languages should be included. Of course, the user should be sure a particular language is supported before purchase.

Third, the package should include a menu-driven control program that would enable the user to perform some simple tasks to ensure the board's function independent of the rest of the system. This would serve two purposes: as an initial check when the user first obtains the board and as a debugging aid in interfacing to the real world.

None of the manufacturers supplies all three elements. For that matter, none seems to offer *complete* software control over its hardware. Range changes, gain changes, and measured quantity (voltage, current, or resistance) were, for the most part, set by switches or jumpers on the data acquisition board inside the PC. No read-back capability is included for determining the resultant board configuration. In a dedicated use, where the board configuration is set for good upon installation, this is not a problem. In general use, however, or when more than one user is involved, each user must check the position of all jumpers and switches.

Technical assistance. All of the manufacturers except IBM provided prompt telephone technical assistance. The representatives seemed capable of handling all software-related questions. However,

METRABYTE			SCIEN. SOL.	STRAWBERRY TREE		WEST. TEL.
DASCON 1	DASH 8	DASH 16	LAB MASTER	ACPC-14-16	ACPC-16-16	ICIS
10^{10}	10^{10}	10^{9}	10^{8}	200,000[a]	200,000[a]	10^{7}
N/A	25	50	100	N/A	N/A	N/A
25	N/A	30	100	10,000[b]	10,000[b]	55
10	5	5	10	10,000	10,000	5
Autozero	Trim	Trim	Trim	See text	See text	Autozero
Autozero	+/−10	+/−12	+/−20	See text	See text	Autozero
—	—	—	—	—	—	—
—	—	—	—	—	—	—
—	—	—	—	—	—	—
—	—	—	—	—	—	—
1	100	10	+/−20	10	10	+/−100
1	N/A	2	+/−20	1	1	+/−35
+/−25	+/−25	+/−25	+/−35	+/−100[c]	+/−100[c]	+/−100
+/−0.01	+/−0.02	+/−0.02	<0.01	+/−0.04	+/−0.04	+/−0.01
—	—	—	—	—	—	—
—	—	—	—	—	—	—
—	—	—	—	—	—	—
60	N/A	90	80	50/110	50/110	70/110
10	10	10	10	—A	—[d]	10

The manufacturers' specifications quote the input characteristics of the board for a zero input impedance. The actual value should be recalculated for the nonzero value of a given application. The change injection value for the IBM board is comparatively high. The voltage offset and voltage drift with temperature are not specified separately for the Strawberry Tree boards.

METRABYTE			SCIEN. SOL.	STRAWBERRY TREE		WEST. TEL.
DASCON 1	DASH 8	DASH 16	LAB MASTER	ACPC-14-16	ACPC-16-16	ICIS
Trim	N/A	Trim	Trim	10%	10%	0.1%
12	N/A	12	12	8	8	12
No	N/A	No	No	No	No	No
0.5	N/A	0.5	0.5	0.5	0.5	0.3
+/−10	N/A	+/−5	10	—[a]	—[a]	10
+/−30	N/A	+/−10	30	—[a]	—[a]	10

The D/A output characteristics show a variation in the maximum load capacitance that can be applied without ringing.

only a few could provide answers when the inquiries turned to analog circuitry, specifications, or interfacing.

INTERNAL ACQUISITION

Some of the manufacturers represented here offer more than one data acquisition product or combination of elements. As mentioned previously, tables 1 and 2 capsule the boards' basic features and significant components, respectively. In addition, table 4 summarizes their electrical characteristics, and table 5 lists their D/A attributes.

Tests were conducted using an Electronic Development Corporation DC Voltage Calibrator, with an overall accuracy to within 20 ppm, a Keithley 191 5½-digit DVM, and a Hewlett-Packard 3320B Frequency Synthesizer. All tests were conducted at room temperature and nominal humidity.

Burr-Brown. The Burr-Brown modular system occupies at least 1½ card slots; in most cases, 2 slots are required. It is the most flexible system, offering a range of modules and termination boards. (See photo A.)

Although only the motherboard interfaces to the PC edge connector, the daughterboards hang over enough so as not to allow another card to be plugged in. The motherboard is sparse: its only components are two 82C55 parallel I/O ports, a DC-to-DC converter (+5 to ±15 V), and some TTL logic gates; and it is memory-mapped. Connectors across the top of the motherboard accommodate three data acquisition daughterboards in a mix-and-match approach, for hardware customization. Each daughterboard is 3.9 inches

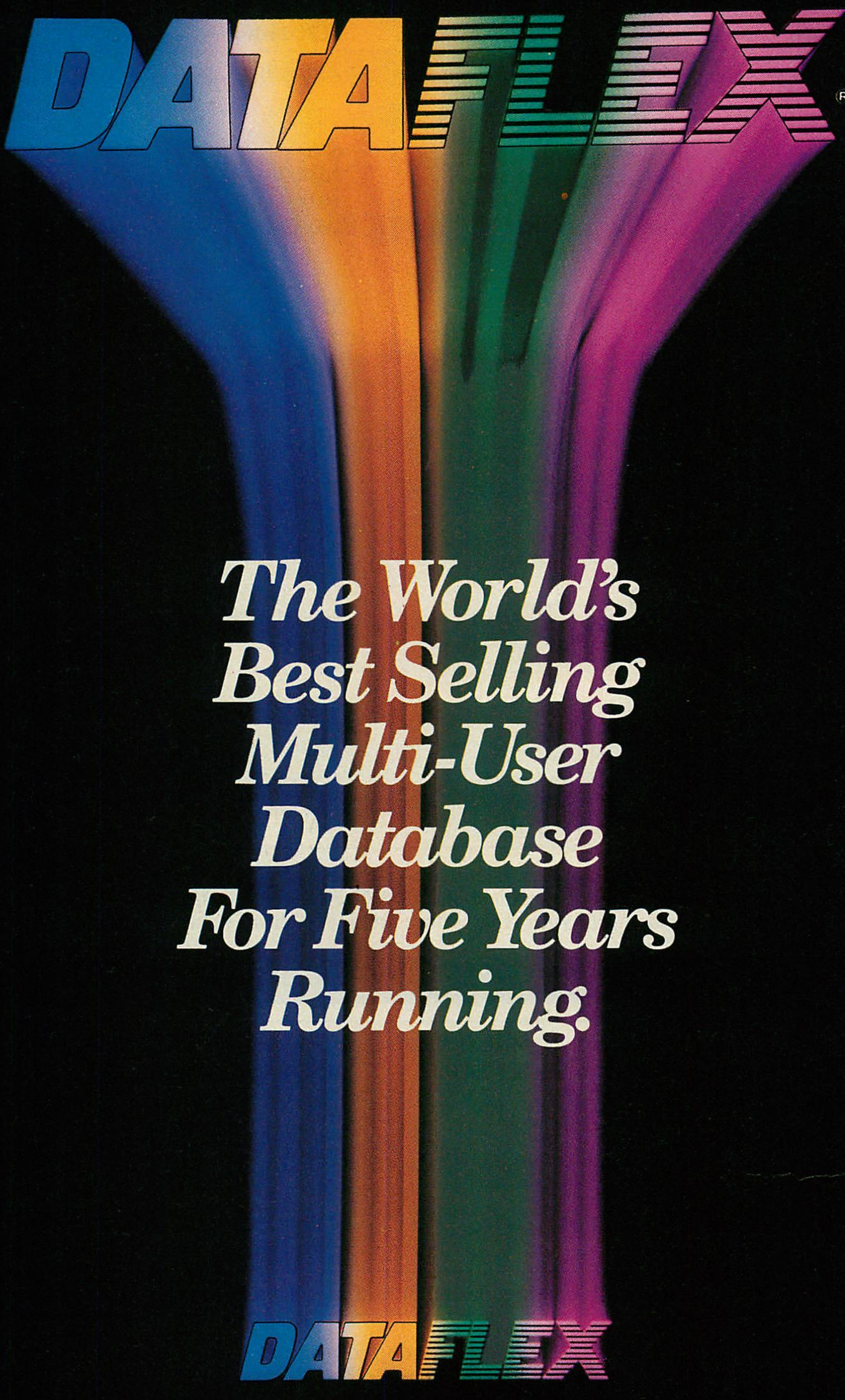

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TABLE 6: *IA BW Limit of 20002 Module*

GAIN	1% ACCURACY	1 LSB ACCURACY
1	71.0 KHz	11.0 KHz
10	21.0 KHz	3.3 KHz
100	4.3 KHz	663.0 Hz
1,000	342.0 Hz	53.0 Hz

The limited BW in the IA section of this Burr-Brown module limits the sampling frequency. This, coupled with the low slew rate of the IA, gives a worst-case limit of 3.2KHz.

TABLE 7: *IA BW Limit of 20019 Module*

GAIN	1% ACCURACY	1 LSB ACCURACY
1	43.0 KHz	6.6 KHz
10	4.3 KHz	663.0 KHz
100	427.0 KHz	66.0 Hz
1,000	43.0 Hz	6.0 Hz

This Burr-Brown module also has a limited BW. Because the IA cannot be bypassed, this places a limit on the maximum signal frequency that can be accurately collected to 1.6 KHz.

square and contains an identifier that can be read by software for a simple installation. One nice design feature of this system: the motherboard and all daughterboards are of four-layer construction. This greatly attenuates PC-induced noise.

The motherboard reviewed (20001C-2) comes with 32 digital I/O ports. The digital I/O lines provide normal LSTTL input and output drive levels. Another motherboard is available without this option (20001C-1). Injudiciously, the digital I/O connectors are located at the far end of the board, and the nonshielded cables that connect them to the outside world must travel across each of the analog modules. This increases the amount of digital noise pickup by these modules. Although installation of the modules into the motherboard and motherboard into the PC is easy, the routing of more than one shielded I/O cable through the back panel is cumbersome. All of the termination panels were of simple printed circuit boards, and mounted on standoffs. Each had sufficient area for supplementary interface circuitry.

Seven Burr-Brown modules were reviewed. Three others are available: a trigger alarm module that can initiate conversions, a digital I/O board, and the 20021, which provides eight channels of analog output by multiplexing a single D/A converter.

The 20002 Analog Input Module is a 16-channel, single-ended or eight-channel differential input 12-bit A/D system. The input multiplexers are Burr-Brown's version of the Harris 508 (BB MPC8S). An instrumentation amplifier (Burr-Brown PGA200) gives programmable gains of 1, 10, 100, and 1,000. It is followed by a National LF398A sample-and-hold that feeds a Harris 574AKD 12-bit A/D converter. The total conversion time for a given signal ranges from 40 microseconds for a single channel to 83 microseconds for multiple successive channels when using unity gain. A gain of 1,000 requires slowing the overall conversion time to 753 microseconds. Total conversion time increases as the gain increases due to the necessary settling time in the instrumentation amplifier. Note that although the offset can be trimmed to zero for each gain, appropriate compensation must be made in the software (or a channel must be designated for autozero) if more than one gain range is used. Tests revealed that the gain does not have to be tweaked between ranges, because the gain inaccuracy is only 0.02 percent on each range. The A/D range can be changed by jumper for −5 to +5 V, 0 to +10 V, and −10 to +10 V.

Offset voltage drift is 100 ppm per degree centigrade (approximately ½ LSB) for unity gain. This improves dramatically, to 20 ppm, for the other gain ranges. The linearity inaccuracy of the programmable gain amplifier showed a loss of about two bits of the A/D resolution. Users should note with caution that the high bias current shown with testing could cause significant measurement errors even with small source resistances. On the gain-of-1,000 range, a 1.6-KΩ source impedance displayed an offset of 1 percent of the range. Even though this module's I/O cable is shielded, tests showed ten counts of noise on the gain-of-100 range and four counts of noise on a gain of 10. This is a good argument for not using higher gains inside the PC in conjunction with successive approximation converters.

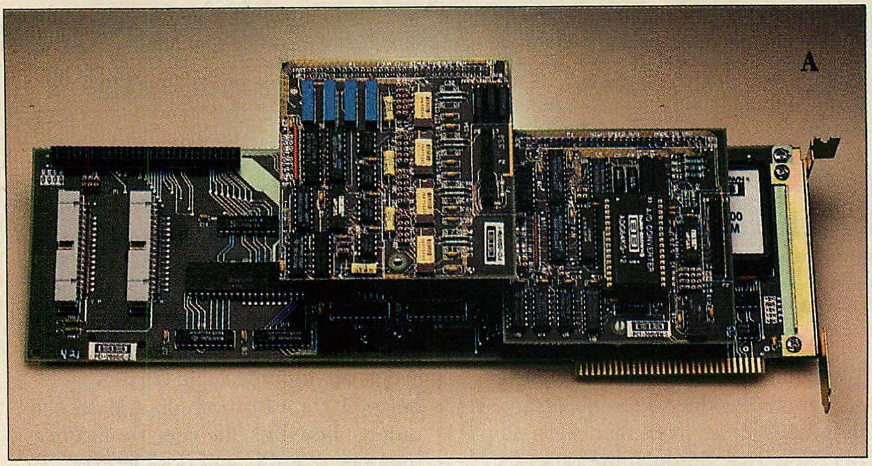
The module is capable of converting a single channel in 31 microseconds. However, testing showed that the limited bandwidth in the instrumentation amplifier limits the maximum conversion frequency (see table 6). In addition, the relatively sluggish slew rate of the instrumentation amp (0.4 V per microsecond) limits the maximum signal frequency for a full range input (20 V peak to peak) to 3.2 KHz.

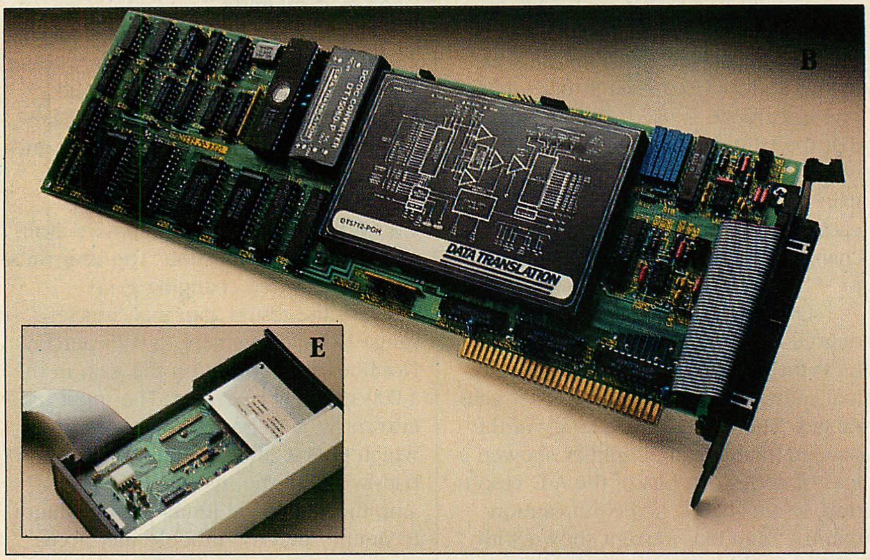
The 20005 Analog Input Expansion Module, which consists of four Harris 508A multiplexers, is configurable to give an additional 32 single-ended or 16 differential input channels. Input capacitance ranges from 5 pF off channel to 30 pF on. Input leakage current is below 100 pA for both on and off conditions; however, the user should remember that this will double every 10 degrees centigrade.

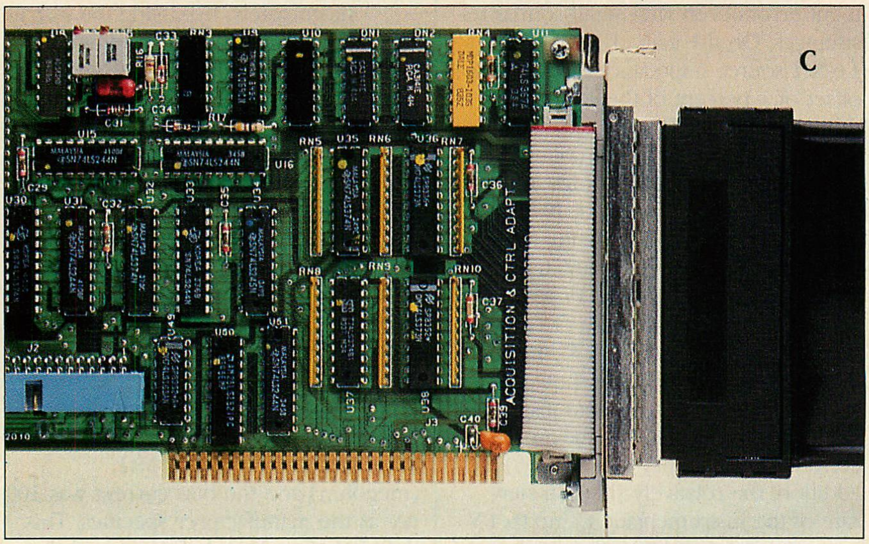
Providing a means to grab four channels of data simultaneously without the accompanying time skew is the 20017 Sample-and-Hold Module. Each of the four National LF398A sample-and-holds is preceded by a Burr-Brown INA102G instrumentation amplifier. Gains of 1, 10, 100, and 1,000 are available by jumper selection. The user must recalibrate when changing gains because the tested gain inaccuracies range from 0.1 percent to 0.75 percent. Nonlinearity is worst on the gain in the 1,000 range: 0.1 percent. The input bias current is ±50 nA (nanoamperes)—which puts it on the high side. The low bandwidth of the instrumentation amplifiers severely limits the maximum frequency that the module may accurately acquire (see table 7).

Unfortunately, bypassing the instrumentation amplifiers and feeding the signal directly into the sample-and-holds is not possible. The abysmal slew rate of the instrumentation amplifiers limits the maximum signal frequency for a full range input (20 V peak to peak) to 1.6 KHz.

The 20019 High Speed Data Acquisition Module sports a fast monolithic sample-and-hold (Teledyne Philbrick 4866) followed by a 10-microsecond conversion time A/D (Burr-Brown ADC84KG). The input is multiplexed by a Harris 508A providing eight single-ended input channels. The input resistance was measured as 1 MΩ (megohm) and the bias current was 100 nA, as the manufacturer specifies. This definitely is a module for use with low source impedances for high-frequency applications. Throughput can be as high as 87,000 samples per second. Both gain and offset drift are generally negligible. The 2-MHz gain bandwidth of the sample-and-hold permits 1 LSB accuracy to 44 KHz. Gain and offset should be readjusted if the jumpers are configured







The modular system of the Burr-Brown product (photo A) enables the user to create configurations for specific applications. The addition of these modules makes the board overhang the adjoining slot such that it is not possible to put in another card. In photo B, the Data Translation module that contains the A/D converter is apparent on the data acquisition board. This module also is used by Scientific Solutions (photo E inset), but on the LAB MASTER, the module is in the external connection box, not on the main board. In photo C, the shielding of the cable on the IBM configuration extends onto the board, making a true shielded system. None of the other boards has this essential feature. This board's I/O connector is at the logical end so that analog signal lines do not cross circuitry unnecessarily.

for an alternate range—those available are ±2.5 V, ±5 V, ±10 V, 0 to +5 V, and 0 to +10 V full scale.

Burr-Brown's 20003 and 20006 are Dual D/A Converter Analog Output Modules with 12- and 16-bit resolution, respectively. The 20006, however, is accurate and monotonic in nature over a 14-bit range because it uses a Burr-Brown DAC709. Its drift is in the range of a few LSBs per degree centigrade. On the 20003, the temperature drift of the Burr-Brown DAC811 is negligible. The user must not load the output with more than 500 pF of capacitance (cable plus load) in order to prevent ringing and possible oscillation. Both modules can force 0 to 10 V, −5 to +5 V, and −10 to +10 V, jumper selectable. Output current is limited to ±5 mA. Both modules require recalibration when changing ranges.

The 20007 Counter/Timer/Pulse Generator Module supplies four general purpose, 16-bit counter/timers and a flexible rate generator with an output frequency of from 0.002 Hz to 2 MHz. All inputs and outputs are TTL compatible. This device also can serve as a useful time base generator for A/D modules on the same motherboard. The module is built around two 8254 counter timer chips that use an 8-MHz crystal as their main time base.

One price the user pays for modular flexibility is the amount of flipping necessary in using the documentation—from the software section, to the information on the motherboard, then back to the details on a particular module, and finally to the description on the termination panel. Even so, the information is clearly written. Each module manual provides sufficient information for the user to write low-level drivers. Burr-Brown supplies an 8½-by-11 binder that accommodates the separate information packets.

The company's software interface consists of high-level support routines for BASIC, C, and Turbo Pascal. Moreover, sufficient information is provided on the lower-level mechanisms of interfacing to these drivers to make it possible to use them with assembly language. The 22 support routines share common ancestry, which makes it convenient for the user who programs in multiple languages. He must be careful, however, to load the correct driver for the language in use. This is accomplished by running the appropriate program one time upon powering up. The manual includes six sample programs in each of the three supported languages, with excellent documentation.

PHOTOGRAPHS • DAVID ARY

Technical questions are fielded by an apparently knowledgeable and energetic staff. Burr-Brown was one of the few manufacturers that could provide answers to analog-related questions.

Data Translation. An Intel 8742 helps to control the Data Translation data acquisition board: the DT2801-A exhibited the fewest design flaws of the products reviewed and its performance was quite acceptable. A total of 16 single-ended or eight differential 12-bit analog input channels, two 12-bit analog output channels, and 16 parallel I/O lines are packed onto the card. A variety of analog input options are available by changing the analog input module. The reviewed board contains Data Translation's DT5712-PGH module with four programmable gains: 1, 2, 4, and 8 (see photo B); the DT5712 module itself is a shielded enclosure for the A/D, an excellent precaution. (More on the DT5712 module is provided in the discussion of Scientific Solution's system.)

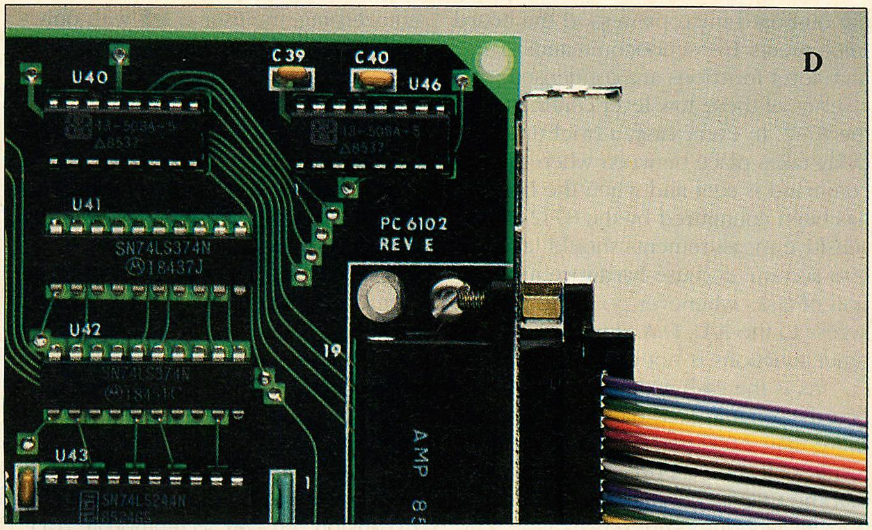
The maximum throughput to memory was specified as 27,500 samples per second. Overall input accuracy is ±0.05 percent for any gain, and gain and offset drift with temperature is negligible. Tests showed that the high bandwidth of the limited gain instrumentation amplifier provides for accurate performance up to the Nyquist rate (13 KHz).

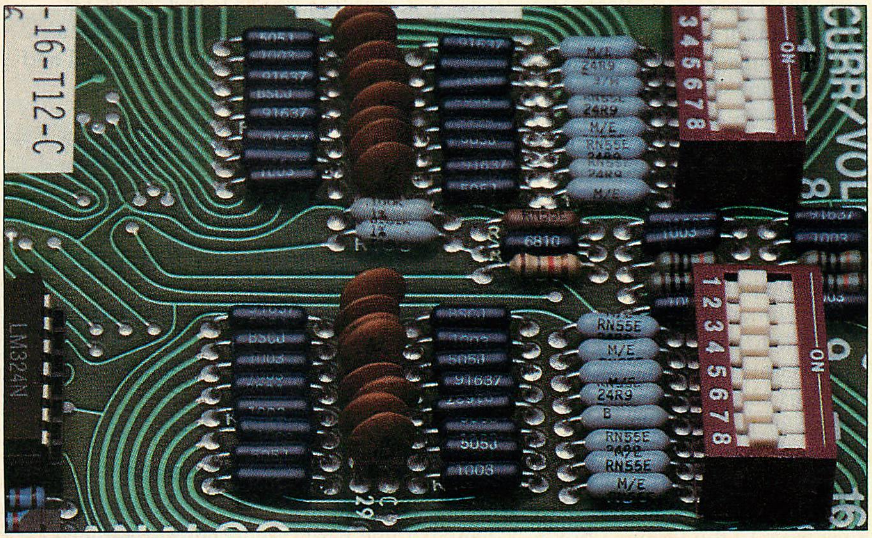
Tests also revealed that the D/A channels are compensated for capacitive loads to 0.5 microfarads. As usual, changing the range requires recalibration. Drift in offset and gain is roughly 1 LSB per 10 degrees centigrade.

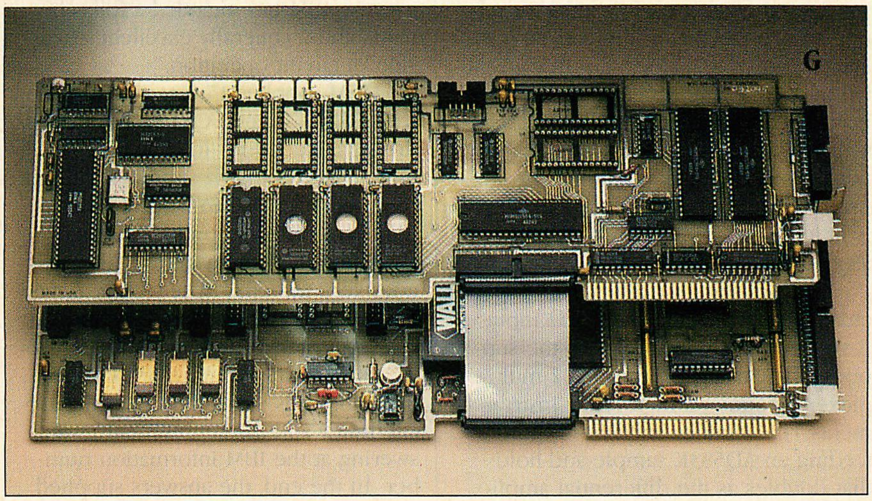
The board installs easily. The three-foot unshielded ribbon cable connects to the card and the terminal printed circuit board, mounted on rubber feet. The terminal card brings out the signals to barrier strip screwdriver connections. Space is provided for an optional cold junction sensor. This is of limited value, however, because no isothermal plate is present to keep the sensor at the same temperature as the connections.

Two manuals are packaged with the board. The first details hardware aspects, low-level programming, and programming in BASIC. The second is the user manual for the PCLAB machine language routine library; it provides high-level functions for BASIC, C, FORTRAN, Turbo Pascal, and assembly language. Neither manual has an index, and page flipping becomes the rule; however, the information is complete and clearly written.

The lowest level of programming requires sending a command byte followed by optional parameter bytes to







The MetraByte DASH 16 board (photo D) has a four-layer construction with excellent ground planes around the components. This is a simple and effective method of reducing noise that is not employed by all of the manufacturers reviewed. The disc ceramic capacitors that are used on the Strawberry Tree Acquisition Board in photo F are a surprising design choice. Their temperature stability is not really suitable for this type of application. The Western Telecomputing board pair (photo G) does not have a solder mask, an unusual and substandard printed-circuit board fabrication omission. This set is designed for a slightly different purpose than the other boards reviewed. It can be used in unattended mode for applications with a slow conversion rate (meteorological, for example).

the on-board microprocessor; the board implements 16 pseudocommands. The high-level functions are condensed into a series of these low-level commands to the 8742. In every case, a brief time delay takes place between when the command is sent and when the board has been configured by the 8742. Time-sensitive measurements should take this into account and use hardware initiation of tasks whenever possible. Direct access to the A/D, D/A, digital I/O, and timer functions is not possible.

As is the case with all of the boards, programmed data transfers of more than 2,000 per second require turning off the PC's time of day clock so that the CPU can orchestrate the data transfer without interference.

Data Translation offers technical assistance, but it seems limited. Analog questions that could be researched in the company's better-than-average specifications were handled easily. Tougher questions present a challenge.

IBM. The IBM Data Acquisition Board offers four differential channels of 12-bit analog input, two channels of 12-bit output, 32 parallel I/O lines (16 input and 16 output), and an Intel 8253 for counter/timer applications. Conversion from A/D to memory is specified as 15,000 conversions per second.

This was the only board reviewed that maintained shielding from the printed circuit board to the terminal box (see photo C); however, the connecting cable is not keyed, so the user must trace to the terminal box to locate pin 1 on the cable and properly attach it to the connector on the data acquisition board edge. Aside from this, installation is easy. The terminal box is a printed circuit board with barrier strip screwdriver connections inside a sheet metal box. The data acquisition board itself has a four-layer design, but there is little evidence of ground planes around the analog circuitry.

Each of the four differential input channels is protected by 10-KΩ input resistors and diode clamps to the supplies. The Analog Devices 7502 multiplexer is followed by a Texas Instruments TL064 buffer amplifier before feeding an AD583K sample-and-hold that doubles as the differential amplifier. The 7502 gave the highest charge injection of all the boards reviewed: 150 pC; the system's overall accuracy was within 1 LSB, 0.025 percent; and input bias current was measured as high as 300 nA, which is rather large.

IBM's four input channels are too few for general purpose use. If an application calls for autocalibration and autozeroing, the user is left with only two input channels. Recalibration is necessary when changing (by dip switch) between the ranges of 0 to +10 V, −5 to +5 V, and −10 to +10 V.

The two D/A channels are constructed from 12-bit Analog Devices AD7545KN D/A converters followed by AD644KH operational amplifiers. The reference for each channel is stolen from the A/D converter. Output ranges are 0 to +10 V, −5 to +5 V, and −10 to +10 V, and require recalibration when changed. IBM does compensate its output amplifiers to accommodate capacitive loads to 0.5 microfarads.

Two 34-pin ribbon cable connectors located on the board for IBM's expansion bus will accommodate data acquisition products that are as yet unreleased. The package includes a well-documented software manual and a fine hardware technical reference manual. IBM has included a full schematic and a generally excellent discussion of circuit operation.

IBM's board maintains shielding from the printed circuit board to the terminal box; but the connecting cable is not keyed, so the user must do some tracing.

IBM supplies 15 functions for use with BASIC, C and FORTRAN. A device driver, included for loading at boot time, requires only a simple addition to the user's CONFIG.SYS file. The functions share a common heritage, so changing from language to language goes very smoothly. The technical manual provides information to enable the user to write his own low-level drivers.

Requesting technical information from IBM was difficult; it involved a local dealer and the representatives answering at the IBM information number. In the end, the answers supplied were incorrect or not to the point.

MetraByte Corporation. Three of this company's data acquisition cards were considered. All three have 37 pin-D connectors for connection to the outside world, making their installation easy, and all three are I/O mapped, with the address selectable by DIP switch. An unshielded ribbon cable connects the card to a plastic terminal box which contains binding posts and some auxiliary circuitry mounting space.

The half-card DASH 8 accepts eight single-ended analog input channels through its Harris 508A multiplexer. A National LF398 performs the sample-and-hold and a Harris 574AJD A/D converts the data. It is permanently configured for a −5 to +5 V range. Conversion time of the A/D is a maximum 35 microseconds, and its overall accuracy is specified as 0.034 percent. Acquisition time of the sample-and-hold typically is 15 microseconds. Its input current was rather high at 100 nA maximum, and its gain and offset voltage drift are negligible. The sampling error is slightly larger than for other boards. For example, at an input slew rate of 0.002 V per microsecond, it is 1 bit. If the input is a 10-V peak-to-peak signal at 32 Hz, the sampling error will be an additional bit.

The board also contains eight bits of I/O (four input and four output) and an 8253 counter timer (three 16-bit channels), and it can interrupt the PC on INT 2 through 7, jumper selectable.

The DASH 16 full-size card gives 16 single-ended or eight differential input channels to its 12-bit A/D (Harris 674AJD), two D/A channels, parallel I/O of four lines each input and output, and a three-channel, 16-bit timer/counter (Intel 8253). Conversions may take place at a rate of 35,000 per second on a single channel. The board has a four-layer construction with excellent ground planes (see photo D) surrounding the analog input section.

The card's multiplexers are the ever-popular 508A, and the sample-and-hold is National's LF398. Its acquisition time and sampling error are the same as that for the DASH 8.

The DASH 16 has switch-selectable gains of 0.5, 1, 2, 5, and 10, although the board requires calibration when gain is changed. The instrumentation amplifier is PMI's AMP-01, which yields ranges from ±0.5 V to ±10 V bipolar and +1 V to +10 V unipolar. Gain peaking of the lower gains is quite noticeable in the 10 KHz range (see the comment below in the discussion of the EXP 16). The user should not expect better than 1-percent accuracy for frequencies above 5 KHz. Its data transfers from A/D to memory can be programmed or under DMA control; its overall accuracy at DC is 0.034 percent.

Input current was measured as 10 nA. The specifications showed that the gain drift and nonlinearity are negligible. Offset voltage drift can be as high as ½ LSB per degree centigrade.

The D/A channels are 12-bit Analog Devices AD7548KN followed by PMI OP-07s; loading the outputs with more than a few hundred picofarads is not recommended. A unique feature of this board is that the input to the D/As can be either an on-board reference voltage for normal output voltage generation or a user-supplied signal. This could be used as an AC signal amplitude control, for example. Both gain and offset drift with temperature are negligible.

MetraByte's DASCON 1 is the low-frequency (30 conversions per second) integrating A/D cousin of the above two boards. Each of the four input channels is protected to 120 V RMS and multiplexed by a CD4052. Full-scale input voltage is ±2.0475 V. The A/D is a Teledyne 7109, 12-bit A/D, and sign converter. Its accuracy is 0.034 percent. Gain and offset drift are negligible and input current is 1 nA maximum. The reference is a National LM329BZ.

Two of the input channels are configurable as RTD (resistance temperature detector) inputs, with built-in 1-mA current source. The other two channels may accept optional National LM363 instrumentation amps for gains of 10, 100, and 1,000. Input current then increases to a maximum of 10 nA. Instrumentation amplifier gain cannot be trimmed (except to within 1.5 percent); the user will need to calibrate with a known voltage and handle compensation in the software. Offset voltage can be trimmed, but it can drift a maximum of 10 LSB per degree centigrade. The common mode voltage range is on the low side: −2.7 to +3.8 V.

The board is made complete with a battery-backed realtime clock, 12 bits of parallel I/O, and two D/A channels (Analog Devices ADDAC80NCBI-V). Light capacitive loading (less than 1,000 pF) is recommended. As with the other boards, the D/A converters require recalibration if their range is changed.

The EXP 16 is a 16-analog-input expansion interface PC board that can be daisy-chained and is mounted on standoffs. It can be used with the DASH 8 or the DASH 16. Although a thermal sensor is present on the 4.7-by-8-inch board, it is not in intimate thermal contact with the terminal blocks. The board contains two Harris 506A multiplexers and a PMI AMP-01 instrumentation amplifier. Eight switch-selectable gains from 0.5 to 1,000 configure the overall gain for all channels. Gain and offset will have to be tweaked whenever the gain range is changed. Settling time to 0.01 percent varies from 12 microseconds for low gains to 50 microseconds for a gain of 1,000. The PMI AMP-01 gain versus frequency is adequately controlled for all except unity gain. In that case, the user should be cautious if the frequency of the input signal exceeds 10 KHz. The PMI AMP-01's frequency response has a 5-dB peak at 100 KHz. In fact, signals at 10 KHz showed three-percent peaking relative to a 1-KHz signal. The board is delivered with 8-Hz filters on all input channels; the filters consist of a 10-KΩ resistor from each of the inputs, which are bridged by a 1-microfarad capacitor. Each channel on the board requires a 170-millisecond settle time to 1 LSB.

Nonlinearity of the PMI AMP-01 is nearly nonexistent, as is gain and offset voltage drift, except for the gain 1,000 range. There, the offset voltage drift can be ½ LSB per degree centigrade.

The documentation on all three data acquisition boards is clear and well presented. MetraByte goes so far as to offer assistance, albeit limited, on interfacing and grounding applications. The only omission is an adequate referencing of the programs on the accompanying disk. As it is, the user must load and list each one, and read the comments, to find out what each program does.

The LAB MASTER outputs are not protected and supply only 5 to 10 mA of output current. When loaded with a few thousand picofarads of capacitance, they oscillate.

Compared to other documentation, the EXP 16 manual is shockingly inadequate. MetraByte installed 8-Hz filters on all channels, yet the specifications call for the board to be without filters. No instructions are included for removing the filters (which requires desoldering), and the user must trace circuitry on the board to determine which components require removal.

BASIC was the language of choice with these products. The drivers are loaded using either a BASIC program called LOADCALL or by placing a standard header at the beginning of each applications program. The interface to the drivers is accomplished through BASIC CALL statements. All three cards interface to BASIC in the same way. The DASH 8 and DASH 16 provide 17 high-level commands, the DASCON 1 provides 10. Sufficient information is provided to interface to the cards with user-supplied low-level software. Source code is available for the drivers, permitting the user to interface to other languages. BASIC programs were included for thermocouple linearization and for graphing results of data logging. The source code is accessible for all routines.

MetraByte's technical assistance was minimal in dealing with analog-related questions, but response time was good.

Scientific Solutions. The Scientific Solutions LAB MASTER, previously known as the Tecmar LAB MASTER, was reviewed by *PC Tech Journal* in March 1984 (see "Digital-to-Analog, Analog-to-Digital," Peter G. Aitken, p. 104). The basic board that fits inside the PC accommodates the 24 parallel I/O lines (an Intel 8255), the counter/timer, and the two D/A channels. An unshielded ribbon cable connects the data acquisition board to an external sheet-metal-and-plastic box that contains the A/D section. Connections to the A/D are made at ribbon cable connector headers.

The A/D in the outside box reviewed is a 12-bit Data Translation DT5712 module capable of 30,000 conversions per second (see photo E). The module contains a straightforward successive approximation A/D converter built around an AMD 2504 successive approximation register, an Analog Devices 565 D/A, and a Linear Technology 311 comparator. The input multiplexers are Harris 508As, and the instrumentation amplifier is built around PMI OP-15 operational amplifiers. The IA is followed by a National LF398A sample-and-hold. The PMI OP-15 consists of precision BIFET (bipolar and field-effect transistor on the same IC) operational amplifiers with bias current in the picoampere range; leakage current of the input multiplexer, however, brings the input bias current at the module inputs up to the nanoampere level.

Potentiometers are situated on the module for adjustment of offset and full scale gain, but the manual does not address the subject of calibration.

The D/A converters on the board are Analog Devices DAC80s. These 12-bit converters are industry workhorses that consist of a conventional voltage reference, a resistor ladder, current switches, and an output amplifier. The outputs are not protected (other than the output amplifier short circuit current limiting) and can supply only 5 to 10 mA of output current. When loaded with a few thousand picofarads of capacitance, they produce undesirable

oscillation. As with all of the reviewed boards, the oscillation occurs more readily when the D/A converter is forcing a negative voltage. This is caused by the output amplifier. Conventional operational amplifiers use lateral PNP transistors in their output stages for swinging down to the negative supply. These PNPs have low bandwidth (ft) and decrease the phase margin of the overall amplifier when they are active. Both D/A converters require recalibration when the ranges are changed. Ranges can be changed only by on-board jumpers.

The counter timer used (AMD 9513) is probably the best available all-purpose timer for general laboratory applications. Enormously versatile (to the point of confusion), this device can handle nearly any rate or frequency output transducer or counting and timing needs the user may have.

The manual covers the LAB MASTER in all of its forms, including the 14- and 16-modular converters that can replace the 12-bit module. The material was confusing to follow in setting up the system, and the manual was just as difficult to use when looking up information. Programming help consisted of several brief, but very helpful low-level BASIC examples printed in the manual. No disk accompanied the board.

Installing the LAB MASTER requires only a screwdriver, and routing the single unshielded cable to the A/D box through the back panel is easy. Space gets a little tight, however, as the parallel I/O, timer/counter I/O, and D/A converter I/O cables are connected and routed through the back.

The Scientific Solutions technical representatives had difficulty answering analog-related questions outside of the company's published specifications.

Strawberry Tree Computers. Two boards from Strawberry Tree were reviewed. The 14-bit resolution version (ACPC-14-16-T12-A-C) provides 16 analog input channels, 16 bits of digital I/O, or two channels of poorly supported analog output. The 16-bit card (ACPC-16-16-T12-A) drops the two analog output channels and is otherwise the same as the 14-bit card. Each card carries a battery-backed realtime clock.

Testing of both cards revealed that the best specified accuracy is only 0.04 percent, which is a little better than 11 bits, and this is only for the 50-mV and ±25-mV ranges. All other ranges for the boards are accurate to only 1 percent (approximately 7 bits). Current ranges have 1.5 percent basic accuracy; the sense resistor is 10 ohms.

The analog channels are protected to 50 V continuous and 150 V intermittent. The digital I/O channels are nonprotected MOS, although the terminal box can accommodate additional circuitry for protection; the terminal box also provides 7407 buffers for the digital outputs. Two of these boxes are required to bring out all 16 analog and 16 digital I/O channels.

Input resistance for the on channel is 1,000 MΩs for the 50-mV and ±25 mV ranges, but this drops to 200 KΩs when the channel is deselected; the resistance is 200 KΩs for all other ranges. Input current is not specified although it typically will run about 10 nA. Each input channel has a slow filter that consists of two 100-KΩ resistors and a 0.01-microfarads disc ceramic capacitor. The user should take normal precautions to guard against overvoltages in order to prevent dielectric absorption problems with the disc ceramics (see photo F). This dielectric absorption effect was achieved on the review board. Input common mode range is ±8 V.

The program for the Strawberry Tree boards is the best reviewed; the user can select analog scale factors, units, or ranges easily.

These cards include the best reference tested: a National LM399 comes to the terminal box unbuffered. Its connection requires great care.

The A/D converter is a departure from the predominant successive-approximation types. It is an integrating voltage-to-frequency converter built around National's LM331. Resolution and conversion time can be traded off to meet special signal requirements.

The analog input section is optimized for thermocouple inputs. As general A/D inputs, the variation in input impedance and crosstalk between channels acts as a limitation to their instrumentation capabilities.

Although the cards' accuracy specifications are not good, resolution was verified at 14 and 16 bits. Temperature drift specifications are not broken out separately between drift and offset. On the 50-mV ranges, drift is 10 ppm per degree centigrade; on all other ranges, it is 100 ppm per degree centigrade.

These boards can experience a problem when the analog input goes over range. The displayed value may decrease, then go negative on a positive overload. This is especially hazardous in control loops, because it amounts to positive feedback. Also note that input scanning and conversion injects 10-mV spikes of approximately 1-microsecond duration into the inputs.

The analog outputs are ±10 percent accurate. They consist of Analog Devices DAC08 D/A converters, followed by National LM324s. Software support for these two output channels is minimal. The outputs are unprotected and, when loaded with more than a few thousand picofarads, they oscillate.

The manual, which is quite clear, contains the best discussion of interfacing different transducers to the card among the products reviewed. It is one of two manuals that gives a full schematic for the card and terminal box.

The software is excellent for most straightforward data acquisition and control applications. In addition, it is not copy protected. Full source code is available for the BASIC program, as well as for the device drivers on the 14-bit card. The device driver source code is not available for the 16-bit card. The software hooks are well documented and can be incorporated easily into a user's own BASIC program.

Thermocouple linearization is given for types J, K, W, R, A, E, B, G, C, and D. The cards' best accuracy is 0.7 degrees centigrade using an E-type.

The data acquisition and control program supplied with the Strawberry Tree card is very complete and the best reviewed. The user can set the clock; select analog scale factors, units, and ranges; specify channel and I/O names; set alarms on analog or digital I/O; and do some simple control loops. Data logging to disk and/or printer is included. The display of analog input voltages shows resolution down to the nanovolt range, which can be mildly irritating. No provision is made for easily changing the number of displayed digits. Another glitch was that over-range signals can produce in-range readings. The user must be aware of this to prevent positive feedback loops when the product is used in a control system.

Installation of the card with two terminal boxes is abysmal: weaving the four unshielded ribbon cables to four disperse connectors is nearly impossible with only one slot open in the PC. It is highly recommended that the user remove the adjacent card before attempting this installation.

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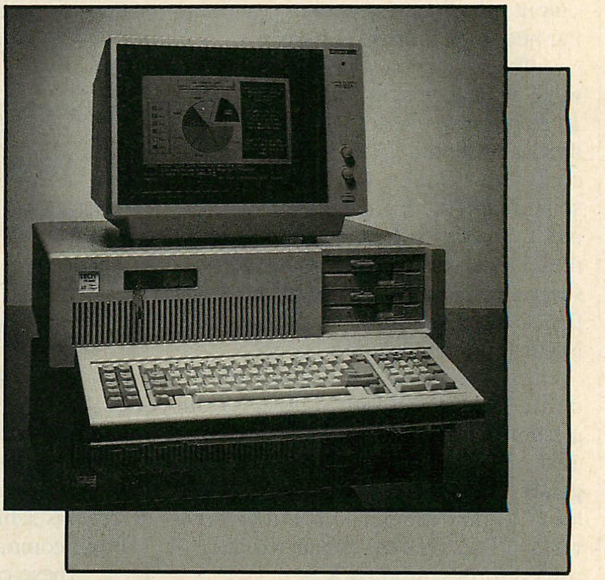

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Layout in the terminal box is very convenient, especially for the analog inputs. They connect to terminal posts mounted in a massive anodized aluminum plate for isothermal contact. The plate has a temperature sensor embedded in the bottom for thermocouple cold junction compensation.

The Strawberry Tree technical assistance was good. The representatives provided accurate information and were knowledgeable about analog circuitry.

Western Telecomputing Corporation. The ICIS two-board set is a unique departure from the other boards covered in this review—a data acquisition system designed primarily for unattended monitoring of meteorological or pollution events (see photo G). Because of this, conversion times are rather slow (10 to 100 conversions per second).

This system also was the only one reviewed that permitted battery backup to allow it to keep acquiring data after power to the PC had been withdrawn.

The two boards are connected to a 19-inch rack-mount termination panel with a 64-conductor unshielded ribbon cable. The boards tested were supplied without solder mask, an unusual and substandard printed-circuit board fabrication omission. Two Harris 506A multiplexers provide 16 differential input channels. Two sockets were left open for an additional 16 input channels. Inputs can be either voltage or frequency. Frequency inputs are counted by an 82C53 and stored in on-board memory; they are controlled by an on-board CMOS microprocessor, an 80C85.

Voltage inputs are routed to one of four instrumentation amplifiers (AD524AD), selectable by software. The amplifiers provide gains of 1, 10, 100, and 1,000. Gain coefficients are stored by the control program to gauge gain inaccuracy, obviating the need for potentiometers. The A/D is built around a voltage-to-frequency converter (Analog Devices VFC32KN) and AD584JH reference. The frequency is counted over a 10- or 100-millisecond period and stored as described above. The effect is that of an integrating A/D converter with excellent noise rejection.

The overall accuracy of the system is 12 bits when the conversion time is 100 milliseconds. Offset voltage is autozeroed periodically by the microprocessor. The gain nonlinearity is less than 100 ppm, and its temperature stability is excellent, with the exception of the 1,000-gain range, which is 100 ppm per degree centigrade.

The realtime clock requires the connection of the external battery backup because it operates in software on the 80C85. Eight D/A converters (two each of Analog Devices AD390JD quad D/A converter) may be installed for 12-bit resolution voltage output.

The accompanying documentation is disappointing. The manual fails to present clearly the necessary information. Locating specific items is further frustrated by the lack of an index.

Western Telecomputing includes what it calls DMS (for Data Monitoring System) in compiled BASIC. DMS is an all encompassing set-up, configuration, debugging, and unattended data logging software package. Menu driven, this software aids the user in quickly setting up the desired configuration and logging in data. Conversions from raw data to engineering units can use built-in linearization with up to a sixth degree polynomial. The system automatically computes and records maximums, minimums, averages, and standard deviation. It also permits timed control of the digital I/O lines. (The source code for this program is not included.)

The primary language link for this product is BASIC. A driver is installed at boot time and is accessed by BASIC CALL instructions; however, the manual's discussions of the 28 high-level commands are inadequate, and the manufacturer's technical support may be necessary to their use. Fortunately, during telephone conversations, the representatives seemed knowledgable.

FITTING THE SYSTEM

It is, of course, understood, that one board cannot satisfy the entire range or even a wide range of measurement needs. The nature of continuous real world data requires that the user tailor the measurement system to a specific problem. For unattended battery-backed operation, for example, the Western Telecomputing set fits the bill and is highly recommended, having been designed specifically for that application. For low-signal-level transducers, predominantly thermocouple, one of the Strawberry Tree boards is a good choice; they are not recommended, however, for general purpose use, especially for voltages above 100 mV.

The price for a particular configuration of data acquisition board also varies according to the specific application. A minimum configuration system can be purchased for as little as $500, but the nature of these products allows many different sized systems to be set up with correspondingly varying prices. The prices for the reviewed boards range from around $500 to $2,300.

For general applications, the Data Translation board is the best bet, encompassing the finest all-around features, excellent documentation, and good software support. It requires only one slot in the PC and installs easily. This board may not be perfect, but neither are these products as a whole.

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Ott, Henry W. *Noise Reduction Techniques in Electronic Systems*. New York, NY: John Wiley & Sons, 1976.

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Eric M. Miller is president of Miller Technology, Inc., a firm that specializes in analog-to-digital hardware/software systems.

Diary of an

I traded my 16K machine and all those disks for Lotus® 1-2-3 and 256K. And immediately got the urge to merge. I started by merging regional statements in Maine. But before I could get to Iowa, I ran out of gas.

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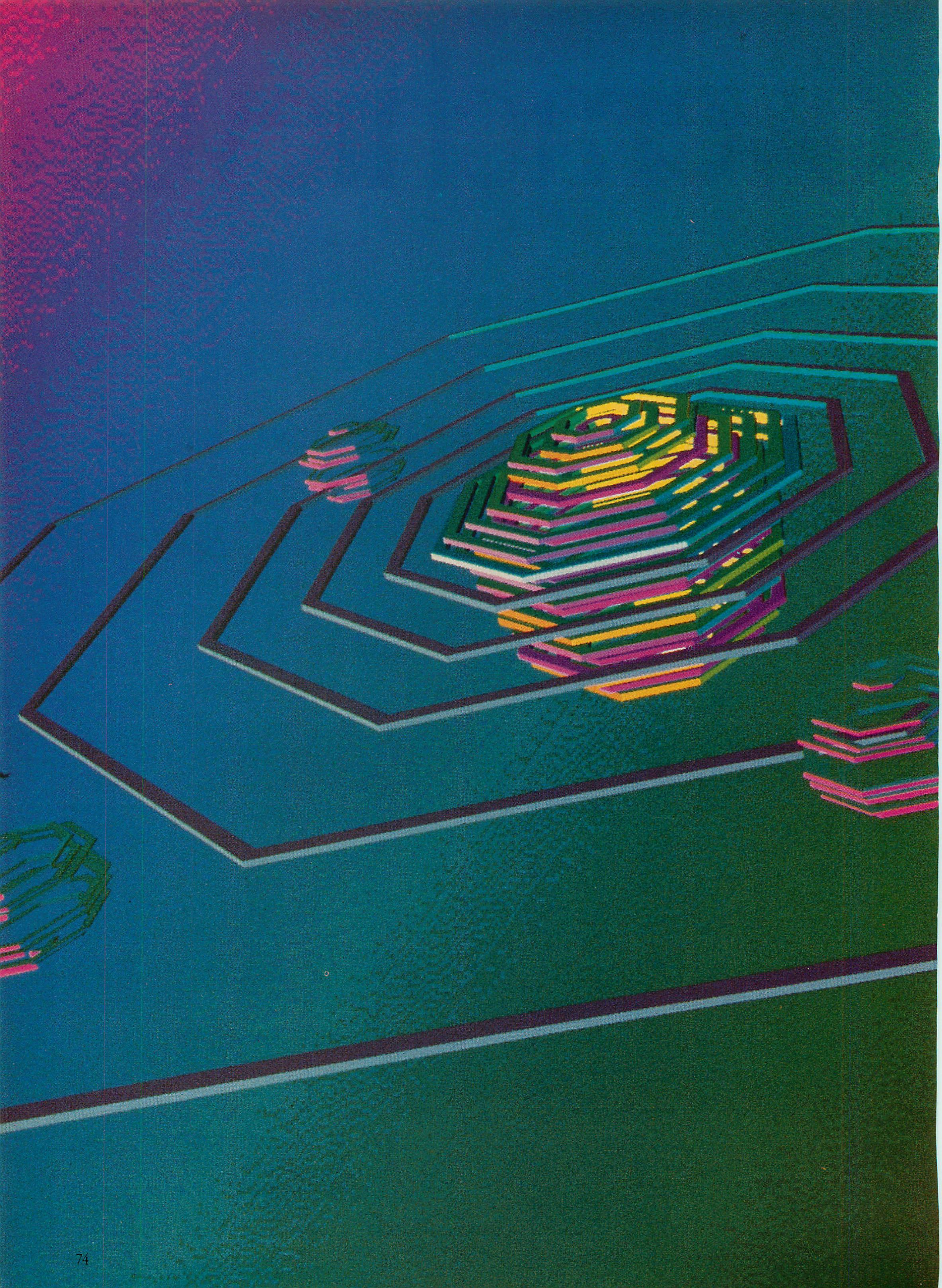

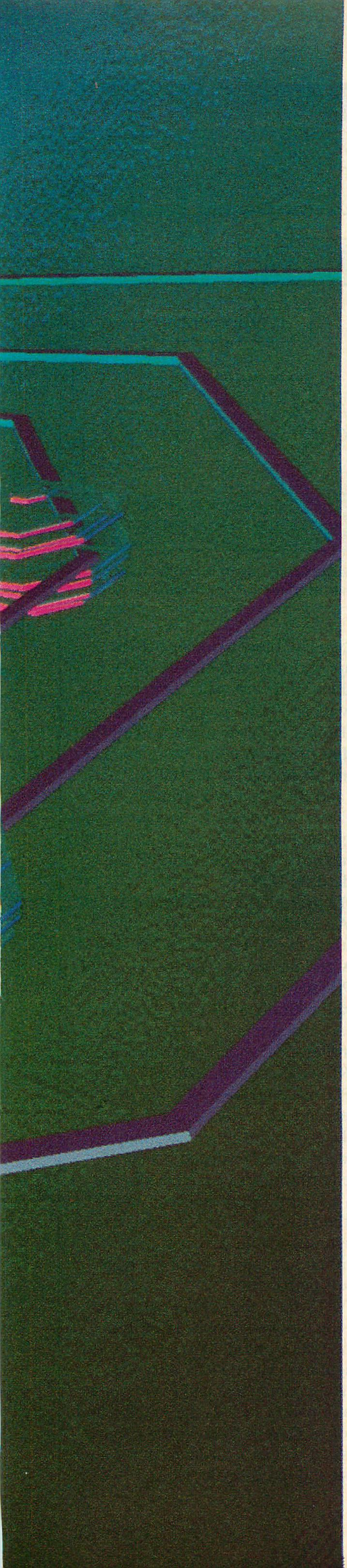

The Portable Approach

The various software components of Hunter & Ready's VRTX achieve portability in two ways: within a processor group and across processor families.

RICHARD M. FOARD

P*ortable* is a word often heard in computer engineering circles. Its usual context is in describing software that can be moved from one operating environment to another by a mechanical process of compiling and linking, with little or no modification of source code necessary. Portability is a quality of utmost importance to businesses because it translates directly into savings of engineers' and programmers' time. Portable software also allows products to be moved more quickly into new markets.

A second dimension of portability is of even greater importance to businesses—the portability of engineers and programmers themselves. The ability to move a product development group from one set of hardware to another without incurring delay and expense for retooling and retraining is a powerful, sought-after business advantage.

Hunter & Ready's VRTX (Versatile Real-Time Executive) family of "silicon software components" is a multitasking, realtime system that offers portability in both senses of the word. Within a processor group such as Intel's 8086 family, its software modules are portable. Across processor families (8086, Zilog Z80 and Z8002, Motorola 68000), its interfaces are identical (see figure 1).

Within a processor family, VRTX software is portable at the executable level. No reassembling, recompiling, or relinking of VRTX's core modules is required in moving from one hardware configuration to the next, and, consequently, Hunter & Ready has the uncommon ability to deliver its software products in read-only memory chips.

The company cites advantages going beyond portability for its silicon software approach. By casting software in an indivisible, nonalterable hardware

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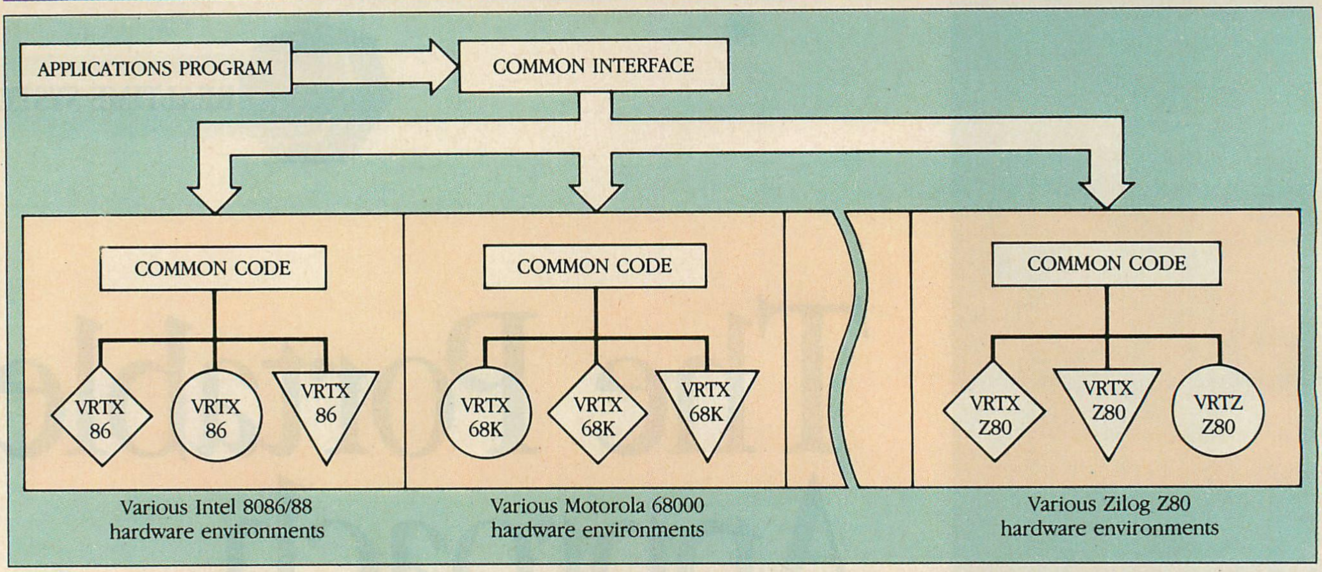
FIGURE 1: *Dimensions of Portability*



Due to the device-independent design of VRTX, the executable code generated on different hardware configurations (shown as different shapes) is portable within the family; across processor families it provides an identical interface for applications.

part, Hunter & Ready moves the character of software development one large step closer to that of the well-standardized environment that hardware engineers have enjoyed for many years. Standard software components encourage a more consistent approach to the task of systems design and simplify product configuration control—the sometimes onerous task of keeping straight which versions of which system components work together properly.

VRTX users need not hunt down the correct versions of the correct vendor's linkers and assemblers in order to create executable versions of VRTX, because inconsistencies in development tools is not a problem.

Version 3.0 of VRTX/86 has four basic modules: VRTX, IOX (input/output executive), FMX (file management executive), and TRACER, a realtime debugging package. The VRTX component provides multitasking, interrupt processing, memory allocation facilities, and a duplex character I/O channel. IOX extends VRTX's I/O capabilities and allows applications programs to control standard or special-purpose I/O devices using a simple, uniform interface. FMX forms a logical layer that may be placed atop IOX and VRTX to manage a structured disk file system. TRACER provides realtime debugging support by allowing "back door" viewing and control of system operations.

Within a processor family, VRTX software is portable among different hardware configurations by virtue of its device-independent design. The VRTX component, even though it provides timing, interrupt processing, and character I/O services, does not rely on any particular clock chip, interrupt controller, or serial I/O device. To use these devices, the executive calls on a configuration-specific device support package (DSP)—a small set of software that users must build to Hunter & Ready's specifications. The DSP provides VRTX with the device-specific intelligence it requires to operate with a particular hardware set.

Its modular design has made VRTX well-suited to the needs of system integrators. VRTX is widely used by developers who manufacture or resell single-board computers embedded in dedicated, special-purpose realtime systems. VRTX system integrators of this type must develop their own DSPs.

VRTX MEETS THE PC

VRTX/86's basic, device-independent modules are delivered in executable form only, either in PROM chips or in hex files on DOS-format floppy disks. Developers using PROM component versions must equip their target systems with an adapter board to host the software chips (see the accompanying sidebar). Developers using the components' software versions can run VRTX in RAM on a PC, XT, or BIOS compatible.

All VRTX code is position-independent. Its only placement requirement is that it be aligned on a paragraph boundary within the PC's 1MB memory space in a location that does not conflict with existing memory or I/O devices. The basic modules use the interrupt vector to accomplish all communications with each other, with the DSP, and with applications code.

Hunter & Ready markets DSPs for a number of common hardware configurations, including the PC DSP for PCs, XTs, and BIOS-level compatibles. A PC developer who elects to operate a component in a mode other than that established by the BIOS must modify the standard PC DSP.

Delivered as a collection of Microsoft Assembler (version 2.0) source modules, the PC DSP stands between VRTX and the devices and resources of the PC (see figure 2). It tailors VRTX to operate with the 8237 DMA Controller, 8253A interval timer, 8259A interrupt controller, 6845 video controller, 8250 USART serial communications controller, PD765-compatible NEC floppy controller, and XT hard-disk controller.

Like DSPs for other hardware configurations, the PC version contains three hardware-specific elements that form a logical bridge between VRTX and the PC's particular hardware set: a configuration table, a system initialization module, and a set of interrupt processing routines.

VRTX finds the configuration table by using a pointer stored in interrupt vector 128 (location 200H). From the configuration table, VRTX discovers operating parameters and environmental information such as the location and size of its RAM workspace, the number of tasks it will be coordinating, the sizes of task and interrupt stacks, and so on.

After establishing a configuration table, DSP initialization code is responsible for the following functions: (1) installing pointers to the configuration table and to VRTX's system call entry point in the interrupt vector, (2) initializing the PC's devices, (3) calling a special initialization routine (VRTX_INIT) within VRTX, (4) performing any required initialization of serial communications ports, interrupt mask, (5) invoking the initialization of an application, and (6) calling VRTX_GO to start the multitasking environment and the applications tasks in motion.

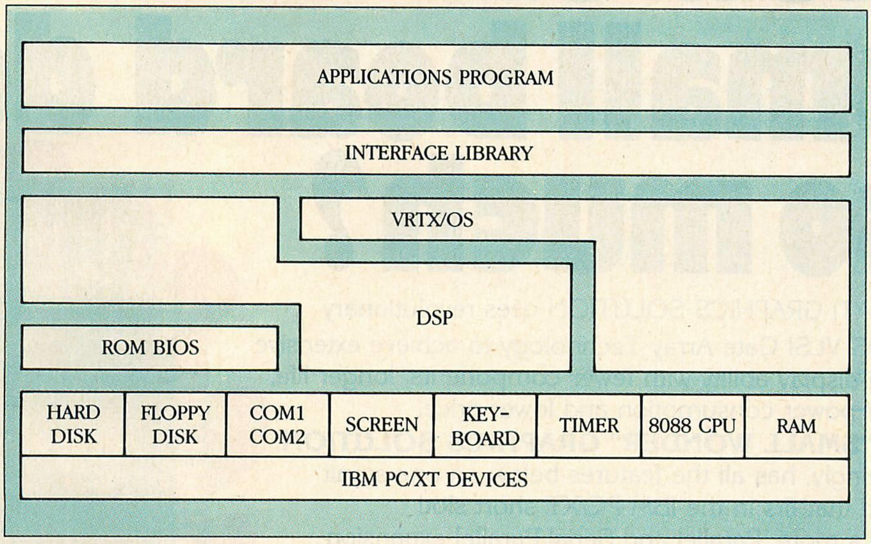
The DSP's interrupt processing routines fill out VRTX's device-independent interrupt processing capability with the device-specific intelligence VRTX requires to manage the PC's interrupting devices. Its timer interrupt processing routine simply makes the special VRTX call UI_TIMER to inform VRTX that a clock tick has occurred; all further clock-based functions are performed by VRTX's generic clock management code.

The DSP's support for VRTX's character I/O channel is more complex. Applications may call upon VRTX to send or receive characters over the serial I/O channel using the SC_PUTC and SC_GETC system calls. VRTX handles all buffering of inbound and outbound characters to a depth of 64 characters, but must rely on device-specific intelligence in the DSP to accomplish physical character I/O.

For receiving inbound characters, VRTX provides the call UI_RXCHR (post received character from interrupt). Each time the DSP's interrupt processing routine awakens and receives a character, it calls UI_RXCHR to pass the character along to VRTX. VRTX buffers the character and, if an applications task has an outstanding SC_GETC call, forwards it to the task when it gets its next opportunity to run.

To send characters out, VRTX provides the call UI_TXRDY. It depends upon the DSP's ready-to-transmit interrupt processing routine to call UI_TXRDY each time a device reports that it is ready to send another character. UI_TXRDY takes a character from VRTX's output queue and returns it to the interrupt routine for transmission. If the buffer is empty, UI_TXRDY returns an error code after noting that the transmitter is now ready; when in this state, VRTX processes the next applications task call to SC_PUTC by calling a TXRDY driver routine in the DSP to transmit the character directly—no buffering is required.

FIGURE 2: *DSP and VRTX/OS in the PC/XT Environment*



The PC DSP contains three hardware-specific elements that form a logical bridge between VRTX and the PC's particular hardware set: a configuration table, a system initialization module, and a set of interrupt processing routines.

TASKS AND SCHEDULING

Once placed in execution by a call to VRTX_GO from the DSP, VRTX establishes a priority-based multitasking environment with preemptive scheduling. Tasks created by the DSP's application initialization phase begin running and contending for processor time. These tasks may in turn create other tasks using the SC_TCREATE system call.

VRTX supports any number of concurrently executing tasks, each running at one of 256 priority levels from 0 (highest) to 255 (lowest). Scheduling is preemptive; VRTX always maintains in execution the highest priority task capable of running. Once in execution, a task continues to run until it terminates itself, suspends waiting for some event, or a higher priority task becomes ready to run. If for any reason a higher priority task becomes ready to run while one with lower priority is running, VRTX switches context immediately and runs the higher priority task.

If several tasks at the same priority level are ready to run, and no higher priority task is ready, the task that most recently became ready to run is executed. If no higher priority tasks become ready while it is running, it retains control until it suspends, at which time it is queued behind all the other tasks with the same priority that are waiting for their turn to execute.

Using the SC_TSLICE (enable/disable time slicing) system call, an application can change the way in which VRTX schedules execution of equal priority tasks. When time slicing is turned on, tasks of equal priority are each allowed a specified number of clock ticks' worth of execution time, then suspended while control is rotated to the next ready task of equal priority. Control continues to be passed in round-robin fashion among tasks of the same priority until time slicing is disabled (or until a higher priority task becomes ready to run). The length of a time-slicing interval is specified in the enabling system call.

VRTX's ability to time-slice among tasks of equal priority is valuable and distinguishes it from other priority-based realtime systems. Systems without time slicing can manage one compute-bound task easily—the task can be given the lowest priority so that it will not block the execution of time-critical tasks. Handling two or more tasks, however, is quite awkward, because the compute-bound tasks must be constructed to pass control explicitly back and forth. They must create self-imposed time slices that are not likely to be as uniform in length as VRTX's clock-determined slices.

The usefulness of time slicing is not limited to the management of processor-bound tasks. Other situations arise in which switching the processor rapidly and evenly among tasks of equal importance is desirable. A designer might want to time-slice among multiple display tasks to avoid haphazard display management that would be disorienting for systems operators. Time slicing is also desirable in time-sharing or other dynamic settings where systems

operators can invoke unpredictable mixes of tasks that must provide reasonably uniform response times.

In practice, the applicability of time slicing is limited by VRTX's behavior when a time-sliced group of peer tasks is preempted by a higher priority task. If this happens before a task has exhausted its time allotment, the preempted task is allowed to start its slice over. In a busy environment, frequent preemptions can defeat time slicing entirely by preventing some tasks from participating in the round robin.

As many as 255 VRTX tasks can be tagged with a unique identification number that allows them to be referenced by other tasks or by interrupt service routines. A task with an identification number can be removed from the system by another task using an SC_TDELETE system call, or it can be made to suspend execution via the SC_TSUSPEND call. Once suspended, a task remains that way until named in an SC_TRESUME call from somewhere else in the system. SC_TSUSPEND and SC_TRESUME provide complete control over a task's operation; a task that is waiting for some event when it is suspended remains suspended even if the event occurs, and it does not proceed until awakened by an SC_TRESUME call. Tasks may apply SC_TDELETE and SC_TSUSPEND operations to themselves as well as to other tasks.

Tasks can use the SC_TPRIORITY system call to change their own execution priority or the priorities of other tasks while processing. They also can discover the priority and status of other tasks by making an SC_TINQUIRY call. By passing the special task identifying number 0, a task can use SC_TINQUIRY to determine its own priority and status.

VRTX's complement of intertask control and inquiry functions provides the systems designer with ample flexibility to build and tune systems with dynamic responsiveness. A task that spends most of its time performing routine, low-priority processing chores, for example, can be coded to elevate its priority temporarily to race through the handling of occasional critical inputs.

The ability of tasks to create, suspend, and resume other tasks allows a designer to place broad control of system operation in the hands of system operators by equipping them with commands to start, stop, suspend, or resume system functions in the midst of processing. VRTX's intertask control facilities enable graceful handling of problem situations. In a process control system monitoring input from several interrupting devices, for example, a command to suspend a particular device's input task can be made available to the operator in the event that a device malfunctions and swamps the system with a torrent of bogus data. In multitasking systems without VRTX's direct intertask control capabilities, giving one task direct control over another's activities is much more difficult.

A VRTX task can temporarily disable VRTX's normal preemptive scheduling of tasks by issuing an SC_LOCK (disable task rescheduling) call. When it receives control back from a call to SC_LOCK, a task is guaranteed that no other tasks will be allowed to run, even if they become ready at higher priorities, until the locking task calls SC_UNLOCK. While between lock and unlock calls, a task shares the processor only with interrupt service routines.

Through locking, the systems designer can avoid the more extreme measure of disabling processor interrupts in order to protect critical sections of code from interruption by other tasks. Also, unlike instructions to disable and enable interrupts, the SC_LOCK and SC_UNLOCK calls nest properly. If subroutine A locks scheduling, calls subroutine B, then unlocks scheduling, scheduling remains locked until A unlocks it, even if B locks and unlocks scheduling in the interim.

The complement of intertask control and inquiry functions provides the designer with ample flexibility to build and tune systems.

MAILBOXES AND QUEUES

VRTX tasks can engage in synchronized communications by sending and receiving 32-bit messages via *mailboxes*, a 32-bit variable declared within an applications module. A task sends a message to a mailbox by passing a 32-bit, nonzero message and the address of the mailbox to the system call SC_POST. If the mailbox is empty, the calling task's message is deposited. If it is not, the caller receives a failure code back from SC_POST. In either case, the calling task remains ready to run.

Messages from mailboxes are obtained in one of two ways. A task calling SC_ACCEPT for a particular mailbox receives and consumes a message if one is present. If the mailbox is empty, an error code is returned. By calling SC_PEND for a mailbox, a caller receives a message if one is present or suspends until one is deposited. If multiple tasks suspend the use of SC_PEND at the same mailbox, the next incoming message is awarded to a waiting task, and the task is allowed to proceed in order of task priority. A task calling SC_PEND has the option of specifying a time limit; if the time limit is reached before a message arrives, the waiting task is returned an error code and allowed to proceed.

Mutual exclusion around a resource or critical section of code can be accomplished easily using VRTX mailboxes. A task requests a resource by calling SC_PEND on its associated mailbox (the mailbox must be initialized to contain a message) and releases it by calling SC_POST to redeposit a message. The releasing call to SC_POST allows the next requesting task to proceed past its call to SC_PEND.

VRTX also provides system calls that manage synchronized data queues of 32-bit messages. Unlike mailboxes, queues are created in VRTX-maintained system workspace memory. Tasks form queues by using the system call SC_QCREATE and passing a maximum queue size parameter and a 16-bit queue ID number by which subsequent system calls can identify the queue.

The three queuing primitives SC_QPOST, SC_QACCEPT, and SC_QPEND are analogous in their operation to the corresponding system calls for managing mailboxes: SC_QPOST enqueues a message or reports failure if the queue is full; SC_QACCEPT dequeues and consumes a message if one is present or reports failure if the queue is empty; and SC_QPEND waits for the arrival of a message if necessary, then dequeues and consumes it. SC_QPOST, like SC_POST, accepts an optional parameter that can be used to specify the amount of time a caller is willing to wait for a message to appear in an empty queue. As with mailboxes, multiple tasks contending for messages from a single queue are awarded messages in order of task priority.

The SC_QINQUIRY system call can determine the number of messages in a queue and the contents of its first message; calling SC_QINQUIRY does *not* consume a message.

Just as a VRTX mailbox can be used to accomplish mutual exclusion about a

resource, a queue can be used to implement resource *pool* management in the style of Dutch theorist Edsger Dijkstra'a semaphore synchronizers. A semaphore is an abstract data structure that can be used with the indivisible, primitive operations **signal** and **wait** to accomplish task synchronization. Each semaphore contains a resource count and a FIFO queue. Tasks wishing to gain access to a unit resource execute a **wait** operation on its associated semaphore. If the semaphore's count is greater than 0, it is decremented and the task is allowed to proceed; if the count is 0, the task is placed at the tail end of a queue of waiting tasks. A task freeing a unit of resource executes a **signal** operation on its semaphore, which increments the count; this allows a waiting task to leave its place at the head of the queue, complete its **wait** operation by decrementing the count, and resume execution.

Given a finite pool of resources for which tasks compete, such as a set of eight serial communications ports through which telephone calls can be placed, an applications system can use a VRTX queue to ensure orderly allocation of the ports as follows: initially, a queue of size eight is created and eight messages are enqueued, each holding the number of an available port; each time a task needs to place a call, it executes an SC_QPEND call to get the number of a free port; when it has finished its call, the task places the port back in the resource pool by enqueuing its number with an SC_QPOST call.

Although in general use the SC_QPOST call differs from Dijkstra's V (**signal**) operation in that it observes task priorities and can fail, it provides a close approximation to **signal**'s operation when the system design guarantees that no task ever attempts a QPOST operation on a full queue.

MEMORY ALLOCATION

Using VRTX's memory allocation calls, an applications system can create memory *partitions* from which fixed-size blocks of memory may be allocated upon request by tasks. Partitions are created using the SC_PCREATE system call. Each partition consists of some number of contiguous paragraphs of memory and has an associated *block*, or allocation unit, size; block size is also specified in paragraphs. An application can create any number of partitions, each with its own block size. A system might, for example, maintain a partition of 100 I/O buffers consisting of 512 bytes each and a second partition of 1,000 message buffers of 16 bytes each. If the need arises, partitions can be enlarged using the SC_PEXTEND call. Tasks request and release individual memory blocks from a partition using the SC_GBLOCK and SC_RBLOCK calls.

The allocator deals in fixed-size memory blocks, so it does not suffer from the memory fragmentation problems possible in variable block-size allocation schemes, and it requires no compaction procedures to reorganize free memory within partitions.

Because a partition is simply a contiguous region of user memory, partitioning affords the user a great deal of flexibility in establishing and using memory pools. A system can, for example, create one partition of very large blocks, then, in turn, define some or all of the large blocks as nested partitions containing smaller blocks.

VRTX's partitioning approach to memory allocation has another important advantage over schemes that parcel out free memory from a single, monolithic pool, as UNIX's **malloc** subroutine does. Partitioning provides natural boundary lines along which a systems designer can divide free memory in order to eliminate system deadlocks. A message switching system, for example, might be designed so that one task receives messages from a communications line, a second reformats them, and a third wraps a new envelope of control information around them and then forwards them out.

As with mailboxes, multiple tasks contending for messages from a single queue are awarded messages in task priority order.

Given this division among tasks, the input task might want to allocate a buffer for each incoming message and queue the message to the reformatting task, which allocates a second buffer to hold the revised message text. This approach raises the possibility of system deadlock if all buffers are allocated from the same pool. A rapid burst of incoming messages could consume all available buffers and leave the reformatting task with no buffers available to hold reformatted messages. Using partitioning, a VRTX-based designer could prevent this type of deadlock by creating two memory partitions and allocating inbound message buffers from one and outbound (reformatted) message buffers from the other.

Communications between VRTX tasks and the standard complement of PC I/O devices is supported by Hunter & Ready's DSP. VRTX users can integrate other, nonstandard I/O devices by adding their own initialization and interrupt service routines to the DSP.

Users have two alternatives when integrating a new interrupt-producing device. If the device's interrupt service routine (ISR) can run completely behind the scenes, with no interaction with VRTX tasks, it can be coded just as an interrupt handler for a simpler environment such as DOS is coded. A service routine for a "watchdog" or "deadman" timer device, for example, which interrupts periodically and automatically causes a hardware reset and system restart if it is not serviced within a short period of time, would fall into this category. Its ISR could save registers on the stack of whichever task happened to be running when the interrupt occurred, service the device, then restore registers and perform an IRET instruction.

If an ISR does require interaction with the multitasking environment, as most do, it must be designed to cooperate with VRTX's task scheduling mechanism. ISRs that must execute VRTX service calls to signal or exchange data with tasks fall into this category. A user-supplied ISR cooperates with VRTX by calling UI_ENTER when the ISR begins executing and calling UI_EXIT when it finishes. UI_EXIT examines the system state to see if any of the actions performed by the ISR could have readied a task of higher priority than the currently executing task. In this way, the higher priority task gets the earliest opportunity to preempt the running task.

ISRs calling UI_ENTER and UI_EXIT can use another element of VRTX's interrupt processing support: automatic interrupt stack switching. If, at system initialization time, the DSP is configured to enable the maintenance of an optional interrupt stack, then UI_ENTER and UI_EXIT perform stack switching as well as cooperating with the VRTX scheduler. In a system configured with an interrupt stack, all interrupt service routines use the interrupt stack instead of task stacks for their local storage. UI_ENTER and UI_EXIT manage nested interrupts properly by switching to the interrupt stack only when interrupt processing is not already in progress.

VRTX, although firmly cast in silicon, supports user-defined extensions to its multitasking environment. VRTX code for creating tasks (SC_TCREATE), deleting tasks (SC_TDELETE), and switching from one task's context to another incorporate *hooks*—calls to optional, user-supplied routines that are executed each time VRTX performs one of these functions. A system indicates to VRTX that it wishes to participate in the processing of these events by storing the addresses of its cooperating routines in the VRTX configuration table.

Internally, VRTX maintains task state information in data structures called task control blocks (TCB). When giving user code a chance to run at these key times, VRTX passes relevant information about the current state of the environment by passing TCB addresses. The user's cooperating routine for task creation receives the TCBs of both the creating and created tasks; the deletion routine receives those of deleting and deleted tasks; and the context switching routine receives the TCBs of the pre- and post-switch active tasks.

User-supplied extensions to VRTX's task management can accomplish a variety of extensions to task environments. A user could choose, for example, to override VRTX's automatic allocation of a fixed-size stack for every task and interject his own code to manage variable-size stacks. If working with a numeric coprocessor or other high-speed, tightly coupled device, a user could extend VRTX to save and restore both the device's registers and the main processor's registers as part of a task's context. User-supplied extensions could even be used to allocate and maintain large, application-specific data structures as part of a task's context, parallel with but independent of VRTX's TCBs.

INPUT/OUTPUT EXECUTIVE

The systems architect whose I/O requirements go beyond the management of a single stream of serial character I/O can benefit from the VRTX family's IOX software component. IOX supports and structures the management of concurrent, buffered I/O operations to character, block, and disk devices.

Applications tasks in a system equipped with IOX are presented with a simple, uniform interface to a system's I/O devices. IOX relieves applications code of the need to know details of its devices' operating characteristics: whether they interrupt, which physical ports and I/O instructions are required to start them working, which transient error conditions may arise, and so on. Applications tasks see only a set of homogeneous I/O channels that may be opened, closed, read, written, reset, and otherwise manipulated (table 1).

IOX's capabilities are tailored to the requirements of realtime systems. In addition to performing basic, direct I/O to devices, IOX can manage buffered, asynchronous I/O operations. In making an IOREAD or IOWRITE call, for example, an applications task can specify that the read or write is to be performed asynchronously—that is, concurrently with the task's continued execution. A task can, in fact, initiate many asynchronous I/O operations to the same or different devices, then, using IOWAIT, wait for notification that the operations are complete. Instead of sitting idle (suspended) while the physical reads and writes are performed, the task is free to proceed with other processing until it absolutely requires the results of its I/O requests.

Partitioning provides natural boundary lines along which a systems designer can divide free memory to eliminate system deadlocks.

Like VRTX, IOX is a position-independent, device-independent software module that must be tailored to its hardware environment by means of user-supplied, device-specific routines.

A systems programmer extending IOX to provide access to a particular device must first determine whether it is a *character*, *block*, or *disk* device. Character devices transfer streams of bytes, usually one at a time; they often produce unsolicited input, as in the case of a keyboard. Block devices transfer data only on request, in sequential, variable-length blocks. Most printers and tape controllers are classified as block devices. Disk devices transfer data on request in fixed-length blocks and are capable of random access across a storage address space.

IOX's buffering and channeling capabilities also provide interfacing to unusual devices that do not fall in one of the standard categories, or they can be used for non-I/O functions, such as intertask communications.

IOX provides a set of generic buffering, timing, and coordination services that may be helpful in user-supplied device management code. It also provides a standard model, or template, of I/O processing logic that a systems programmer fills in for each particular device by supplying device-specific routines. Interfaces to devices that transfer a byte at a time follow a scheme of interaction that is a generalization and extension of that used in the VRTX module for character I/O. IOX's generic services for byte I/O include automatic buffering of unsolicited input (type-ahead buffers) and an optional short-circuit data path for echoing input characters back to terminal devices.

Disk and nondisk block-transfer devices are integrated under IOX by supplying a device service routine (DSR), an interrupt service routine (ISR), and an exception-processing routine. DSRs contain the device-specific intelligence necessary to start devices; ISRs contain that required to process completion interrupts; and exception processors perform special processing when time-out or other conditions arise that may affect an operation in progress.

Upon receipt of an I/O system call from an applications task, IOX consults internal tables and determines, based on the I/O channel identified in the call, which DSR is associated with the indicated device. It then allocates and prepares a device service request block (DSRB), an internal data structure in which IOX tracks the status of an operation as it progresses. The DSRB is passed to IOX's request management module, which activates the device's DSR or queues the request if the device is busy. When the device interrupts to signal completion of its operation, the ISR services the interrupt, interprets the device's status, and passes information to IOX that enables IOX to complete its processing of the application's request. I/O system calls may be given with an I/O priority level, independent of task priority, which determines their treatment relative to other I/O requests.

A device's exception-processing routine is activated when conditions asynchronous with the device's operation arise, requiring special, device-specific handling. A device time-out is one such condition; a request from an applications task to reset a device is another. System-wide conditions may arise that require exception processing for all devices, such as the detection of an imminent power failure.

Just as systems architects can tailor VRTX's task management by supplying hook routines to VRTX, they can augment IOX's processing of I/O requests

for some or all devices by supplying cooperating routines that IOX invokes at four key processing points: DSRB creation, deletion, enqueuing, and dequeuing. By supplying custom DSRB enqueuing and dequeuing routines for a disk drive, a designer can override IOX's default priority ordering of I/O requests, instead ordering them by disk head position or by rotational position.

FILE MANAGEMENT EXECUTIVE

The VRTX family's FMX components manage structured file systems on disk devices. Hunter & Ready supplies one version of FMX for the VRTX/86 family, designated FMX/DOS 86. In keeping with Hunter & Ready's other software components, FMX is device-independent. It creates, reads, and writes file systems compatible with DOS 2.1. Later versions are not yet supported.

Unlike several other commercial realtime systems, FMX does not rely upon DOS itself to provide access to the DOS file system. FMX stands alone and manages the structure of information on the disk directly, duplicating the functions performed by DOS file management code. This approach will keep Hunter & Ready busy creating new versions of FMX/DOS as IBM revises and extends file system structure with new releases of DOS; it also will make VRTX integrators dependent on the company for continued compatibility with DOS. An advantage to this approach, however, is the powerful freedom it has given Hunter & Ready to eliminate the DOS file system's numerous realtime drawbacks—most notably its inability to perform more than one file system operation at a time.

FMX operates in close conjunction with IOX to provide disk volume, directory, and file management services; it depends on IOX for most of its applications interface and all of its physical disk I/O operations.

Applications tasks call FMX directly to create, format, query, mount, and dismount volumes; to create and delete directories; and to create, delete, rename, and manipulate individual file attributes. An applications task reads and writes a file by making one direct FMX call, FMOPEN, to associate an IOX channel with the file, then performing all subsequent operations by making IOX calls.

The cooperation between FMX and IOX is a complex but elegant arrangement. Once a channel has been associated with a file by a call to FMOPEN, applications code makes its read and write requests by calling IOX generic interface routines. The routines, recognizing that the calls reference FMX-managed channels, make intermodule calls to FMX. FMX uses its knowledge of the file system's logical structure to transform the application's requests into calls back to IOX's lower-level physical I/O request processing routines, which read and write physical disk blocks as necessary to accomplish the application's requested file operations. Despite its intimate involvement in file system operations, IOX remains completely ignorant of file system structure.

TABLE 1: *IOX Component*

MNEMONIC	FUNCTION
IOCLOSE	Close a channel
IOCNTRL	Perform special or device-specific operation
IOGET	Perform buffered read
IOOPEN	Open a channel
IOPUT	Perform buffered write
IOREAD	Perform direct read
IORESET	Reset a channel
IOWAIT	Await completion of asynchronous I/O
IOWRITE	Perform direct write

The task does not need to know a device's operating characteristics; it treats all devices the same, and the IOX module provides the interface.

Because file I/O is performed through IOX channels, tasks using FMX-managed files enjoy the same variety of access methods that IOX provides for nondisk, nonstructured devices: file I/O can be buffered or unbuffered, synchronous or asynchronous. Multiple tasks can open channels to the same file and share its use without making any special provisions. Alternatively, a task may open a file for exclusive use, guaranteeing that no other tasks will successfully open it until it has been closed by the exclusive opener.

Random and sequential file operations are supported. Sequential operations include those that are data sensitive—reads and writes that transfer variable amounts of data terminated by a special character. A file user can request that FMX accelerate sequential operations by using a read-ahead/write-behind strategy. When an applications task reads a block from a channel open in this mode, FMX anticipates its next call by reading the next block into memory, perhaps allowing the task's next read request to be satisfied without requiring it to wait for a physical disk read. Likewise, write-behind file write operations do not automatically cause a writing task to wait for completion of the physical write; the data are buffered and the task is allowed to proceed. Applications specify the number of buffers available for use in each channel's read-ahead/write-behind cache when opening a file. A task should not obtain incorrect information due to this mechanism. Read requests will get the most current information by taking it, if necessary, directly from the buffer.

Regardless of whether read-ahead/write-behind management is enabled on some or all file channels, applications tasks can exercise close control over how often data are physically written to disk. Write operations can be issued with a commit option, ensuring that all resulting disk writes be successfully performed before the calling task proceeds. Alternatively, a task can ensure that all modified sectors on a volume are physically written to disk by making the FMX volume management call FDSYNC (synchronize volume).

TRACER

The VRTX family's realtime debugging module, TRACER, allows a systems developer to observe and control the operation of a VRTX system from a standard terminal. Like debuggers for single-task environments, TRACER allows the operator to examine, disassemble, and change the contents of memory and registers and to control system execution by setting breakpoints or executing in single-instruction steps. Unlike generic, single-task debuggers, TRACER has built-in knowledge of VRTX's internal data structures and can examine and control a multitasking system without interfering with its operation.

TRACER can be integrated into a VRTX system with virtually no change to other system components. It requires one serial I/O channel for its communications with the operator, but can be configured to share VRTX's single serial I/O channel. Under the shared channel arrangement, the terminal operator can toggle between VRTX and TRACER with a single keystroke.

TRACER stays out of the multitasking environment's way by running as an interrupt service routine. It accumulates operator commands keystroke by keystroke as TRACER terminal interrupts occur, carrying them out when a newline character is received. TRACER breakpoints are implemented using software interrupt instructions; breakpoint processing is done within the confines of an interrupt service routine.

The operator can run the system either in *command* or *tasking* mode,

switching back and forth between the two as necessary. In command mode, applications tasks do not execute; only the application's interrupt service routines run normally. The operator can inspect or change memory and breakpoints while the system is suspended. In tasking mode, the application runs normally even while TRACER commands are executed. The operator can examine the system state while the system is in motion; TRACER warns if it has captured system state information when it may be inconsistent.

Normal breakpoints cause TRACER to switch automatically from tasking mode to command mode and remain in command mode until the operator explicitly resumes multitasking. Breakpoints may also be set with a report-only attribute; report-only breakpoints suspend multitasking just long enough to display a message at the TRACER terminal, leaving the system in tasking mode. As many as 16 breakpoints may be set, and each may be accompanied by an iteration count. A breakpoint also can be qualified by a task identifier, indicating that system execution should be interrupted only if a particular task encounters the breakpoint; other tasks proceed through it normally.

Given a cooperating user-supplied routine, TRACER supports downloading of an executable system from a development facility via the same channel it uses for operator communications. TRACER can produce formatted displays of system, task, queue, and mailbox states and can locate and display all mailboxes at which tasks are waiting. It also allows inspection of VRTX's input and output buffers. Table 2 is a summary of TRACER commands.

TABLE 2: *TRACER Commands*

LABEL	FUNCTION
DB	Display breakpoints
DI	Display input buffer status
DL	Download
DM	Display memory
DO	Display output buffer status
DQ	Display queue status
DR	Display registers
DS	Display system status
DT	Display task status
DX	Display mailbox pends
HE	Help
IN	Input from port
LI	List disassembled code
OU	Output to port
RB	Remove breakpoint
RX	Resume execution
SB	Set breakpoint
SM	Set memory
SR	Set registers
TC	Switch to command mode
TT	Switch to tasking mode
XS	Single-step execution

The TRACER module requires one I/O channel for communications with the operator but it can be configured to share VRTX's single serial I/O channel.

DEVELOPMENT ENVIRONMENT

Although Hunter & Ready provides DEC VAX cross-development tools, DOS is likely to be the most common development environment for PC-based VRTX/86 systems. Support is provided in this environment for software development in assembly language or in C.

Developers working in assembly language are supplied with include files containing external declarations, system configuration parameter values, and definitions of standard mnemonic names for system calls, parameter packet offsets, error codes, and so on. They are also provided with source and relocatable modules for the components of the PC DSP. Embedded in the DSP is a sample applications system that offers a working example and point of departure for first-time systems builders.

Ironically, developers working with Hunter & Ready-supplied assembly source modules will encounter one of the very problems that the company took great pains to avoid in packaging its basic component modules: development tool incompatibility. DSP modules do not assemble properly under Microsoft's current (4.0) assembler; they require version 2.0. With the older assembler, systems can be generated successfully under DOS 3.1. The officially supported development environment, however, is DOS 2.1, Microsoft's Macro Assembler (MASM) version 2.0, and linker (LINK) version 2.2.

C language development is supported using the Lattice C, Computer Innovations, or Mark Williams C compilers. C developers using VRTX/86 in its standard configuration must compile all modules using the large-memory model. The C DSP contains C header files and a set of compiler-specific system call interface routines for use with all VRTX/86 subsystems.

Whether their target systems are RAM- or ROM-based, developers working in either implementation language can link, generate, and test systems without committing code to ROM. The VRTX/86 alternate-media release package includes assembly modules containing hexadecimal machine language for VRTX, IOX, FMX, and TRACER, from which relocatable modules may be generated for linking into standard RAM-based executable files.

If a VRTX system under development runs well enough to terminate and clean up properly, developers can generate and run a VRTX system under DOS, and then return to DOS without having to reboot.

Documentation for VRTX/86 is impeccable. Documents follow the structure of VRTX software: much of the documentation is device-independent, describing applications and systems programmers' interfaces at a level applicable to systems running on any 8086 family hardware set. For each of VRTX/86's subsystems, a comprehensive document gives the theory of the component's operation and a summary of its assembly language interfaces. Companion volumes give the corresponding C language calling sequences.

The usefulness of VRTX's documentation is enhanced by the inclusion of highly detailed recommendations for sequencing software development and integration tasks. These sections give the type of information that other vendors of complex software products too often leave for the customer to discover alone—by hard experience.

Configuration-specific information on the PC DSP is included in a loose-leaf-bound support documentation set. DSP documentation gives installation and system generation instructions and details the operation of each device driver, including caveats and debugging tips peculiar to the XT's devices.

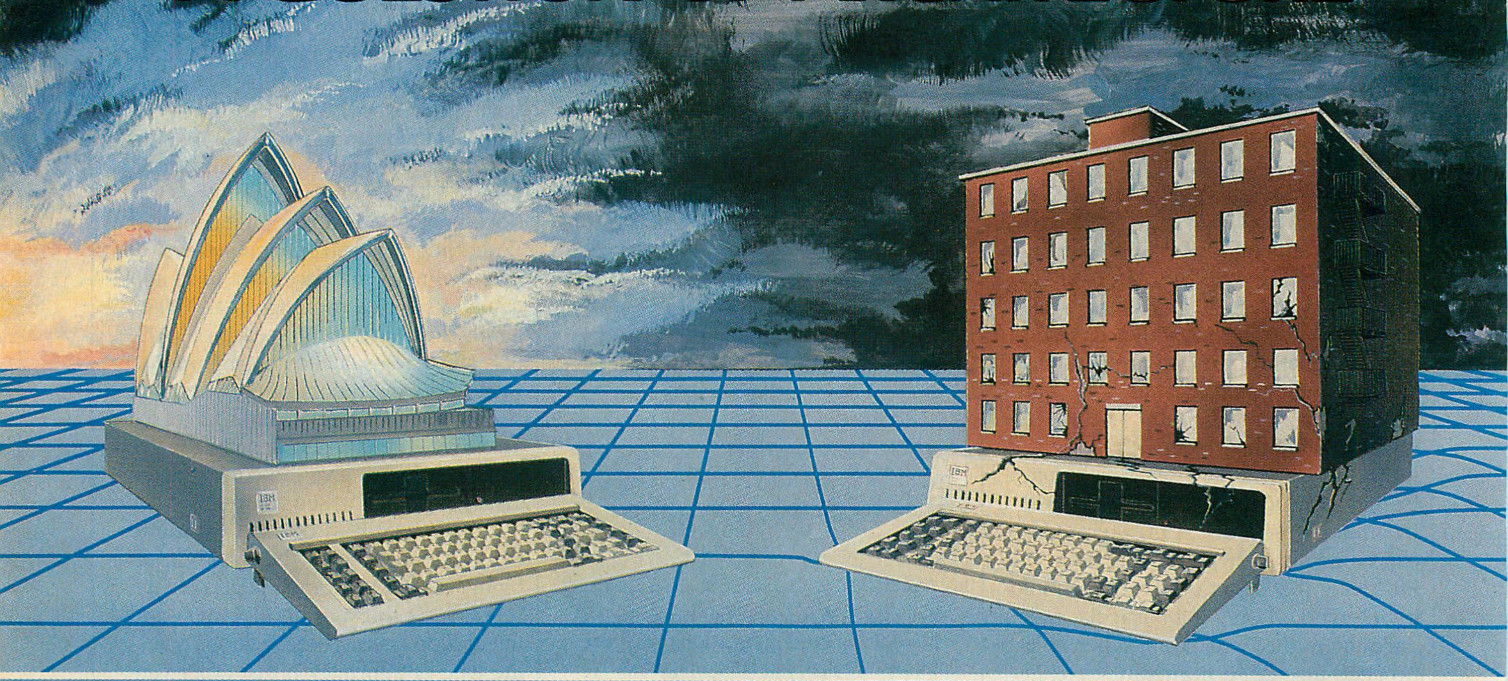
The support documentation package also includes a timing reference giving detailed rules for computing the time consumed by VRTX system calls, context switching, interrupt and I/O processing overhead, and other system operations. Still another section consists of application notes as well as brief articles encapsulating developers' experiences in such areas as "VRTX and Custom Queues" and "[Constructing] Dijkstra Semaphores."

A DOMINANT SYSTEM

Not surprisingly, VRTX has become a dominant realtime system in the microprocessor instrumentation, factory automation, and process control markets for custom hardware systems. It is a mature product that affords a level of realtime, multitasking function equaling or surpassing that found in many minicomputer realtime systems.

QNX vs UNIX

A QUESTION OF ARCHITECTURE



What do QNX and UNIX have to do with architectural design?

The design determines the environment in which you and your applications must survive. If the shear weight of the UNIX operating system brings the PC to its knees, all applications running under it will suffer. Unix was conceived more than a decade and a half ago and the product today is the result of modifications, additions and patches by hundreds of programmers. The result is a large and convoluted piece of software which needs the resources of an AT or more.

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VRTX's design is strong both in its breadth and its depth. It is broad in that its function not only covers all the basic needs of realtime system architects for tasking, timing, and interrupt processing, but also meets more advanced requirements for memory allocation, buffered I/O, and structured file system management. VRTX's design strength is deep in that its components permit tailoring, either by parameter-setting or by user hook routines, at every possible level of operation, from disk volume creation through the lowest levels of task context switching. Its modular, device-independent design has been executed well enough to serve as a model to anyone who is constructing portable, reusable software.

As a vehicle for constructing PC realtime systems, VRTX/86 is attractive both because of its quality and because the availability of its DSP allows developers to start one step past the hurdle of configuring for the PC's hardware set. Users speak highly of VRTX/86's clean interfaces, sound implementation, clear documentation, and Hunter & Ready's cooperative telephone support.

Everything has its price, of course, and VRTX integrators pay the price in system performance for VRTX's generality. The product's sophisticated task scheduling, indirect, intermodule calls, and tests for the presence of user hook routines at every juncture consume processing time that could be spent on applications processing in a leaner, narrower supporting environment.

Hunter & Ready's price structure for VRTX is right at home in the large corporation, custom hardware integration marketplace. It is somewhat alien in the PC market, where declining royalty arrangements are common but software products rarely carry an initial "hurdle" price as high as VRTX's.

Customers building a VRTX-based system must first purchase an R&D package for each of the modules they will be incorporating. This includes five copies of component documentation, a single set of support documentation, including instructions for building a DSP, and a license to make five copies of the purchased component. A VRTX R&D package sells for $5,275. IOX and FMX packages are available for $5,275 and $2,750, respectively, and TRACER is offered for $2,750. Bundled R&D packages combine components at a reduced total price; a VRTX/IOX/FMX bundle, for example, can be purchased for $9,975.

The IBM PC/XT device support package is priced at $2,000. Developers using PC-based C compilers can purchase C interface libraries for VRTX ($500), IOX ($750), and FMX ($500) or all three together for $1,800.

Customers past the development stage purchase software components just as they would quantities of other standard semiconductor parts, on a declining price schedule (the purchase of an R&D package is a prerequisite to volume purchases of VRTX components). Copies of VRTX and IOX are $200 for quantities of one or $75 each in quantities of 100. FMX is $100 for one and $35 in quantities of 100.

As packaged by Hunter & Ready, VRTX is almost certainly not the system of choice for a developer building a one-of-a-kind or even a ten-of-a-kind system. In larger-scale product development efforts, however, its technical merits quickly outweigh its initial cost.

VRTX is not, in fact, out of reach for integrators who are producing modest numbers of systems. Resellers such as DYAD Technology (see the accompanying sidebar) are able to make VRTX available in small quantities at a much lower effective unit price.

VRTX is a standard-setting product of high quality that provides an excellent implementation base to developers of microprocessor realtime systems. Its availability in a PC-configured package will assure it a growing role as the application of PCs in realtime settings continues to broaden.

VRTX/86: see text for price schedule
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CIRCLE 353 ON READER SERVICE CARD

Richard M. Foard is a software consultant who specializes in realtime systems design.

A MEMORY CARD WITH VRTX

Resellers have put VRTX to work in their products, among them DYAD Technology, which offers PC/VRTX, a mapping RAM/ROM memory card that comes with Hunter & Ready's VRTX ROM module installed. A VRTX device support package, configuration utilities for VRTX and the card's memory arrays, and a demonstration multitasking program are included.

In addition to the 8KB VRTX Executive ROM array (expandable to 32KB), the card contains a user ROM array that accommodates 128KB of ROM or static RAM in four standard, 28-pin memory devices, and seven 64KB arrays of dynamic user RAM.

The card allows software-controlled memory mapping. The Executive ROM array can be mapped into any available 8KB block in the PC's 1MB address space. Each of the seven user RAM arrays may be independently mapped into any 64KB block. User ROM also can be made to appear in any block of the address space; its size is determined by the type of memory devices installed.

The PC/VRTX card contains two special bootstrap memory circuits that can be configured to make 64KB of user RAM and the same amount of user ROM available to the PC's processor upon power on/reset. The card can be configured in this way to allow user ROM-resident code to gain control during BIOS's ROM scan or, through use of a patched BIOS ROM, before or at some other point during BIOS/POST (power-on self test) execution. The card's bootstrap memory capabilities can be used to package dedicated, diskless PC systems.

PC/VRTX's software device support package for its on-board VRTX module is delivered in two relocatable libraries for the Microsoft DOS linker. One supports assembly language calling sequences; the second is compatible with the Lattice C (large model) subroutine linkage. The package is accompanied by a manual describing VRTX system calls and DYAD's PC device support package.

Depending on its configuration, this versatile, full-length card can serve as anything from an ordinary DOS memory expansion card to a vehicle for building VRTX-based realtime systems either with or without attached disk storage. (In addition, users can replace the VRTX Executive ROM with their own controlling software if they so desire.)

As of this writing, PC/VRTX is packaged with release 2.5 of Hunter & Ready VRTX, which does not support integration with Hunter & Ready's other silicon software components.

—Richard M. Foard

PC/VRTX: $1,495 with 64KB dynamic RAM; $1,695 with 448KB
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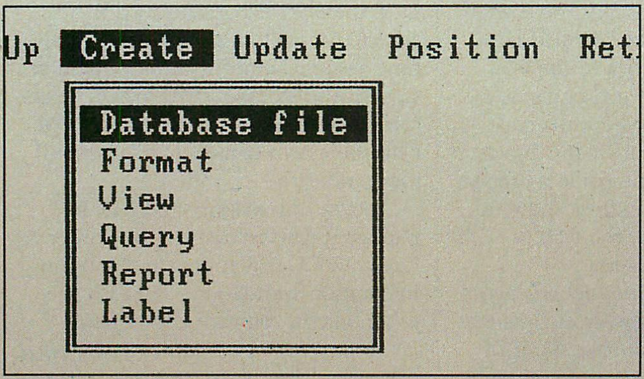

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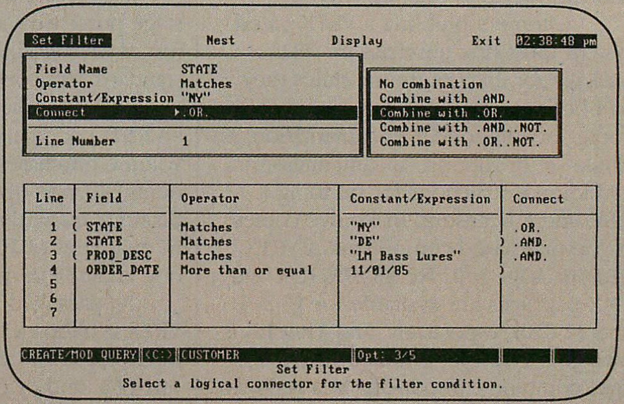

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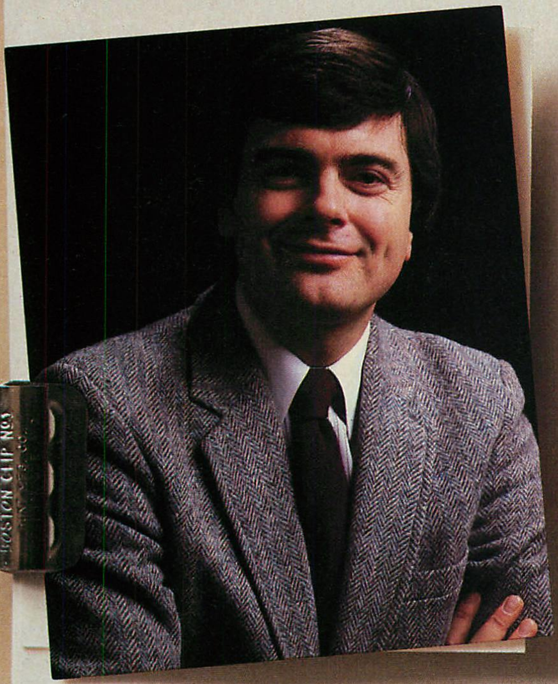

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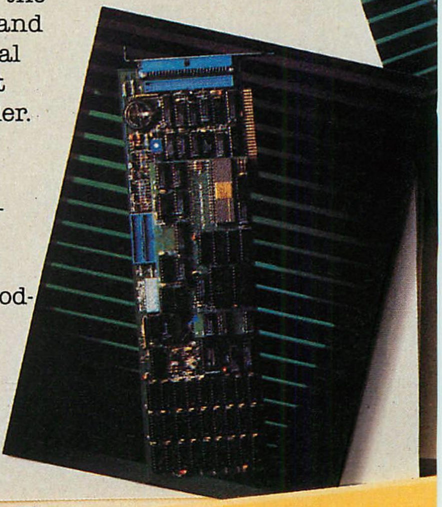

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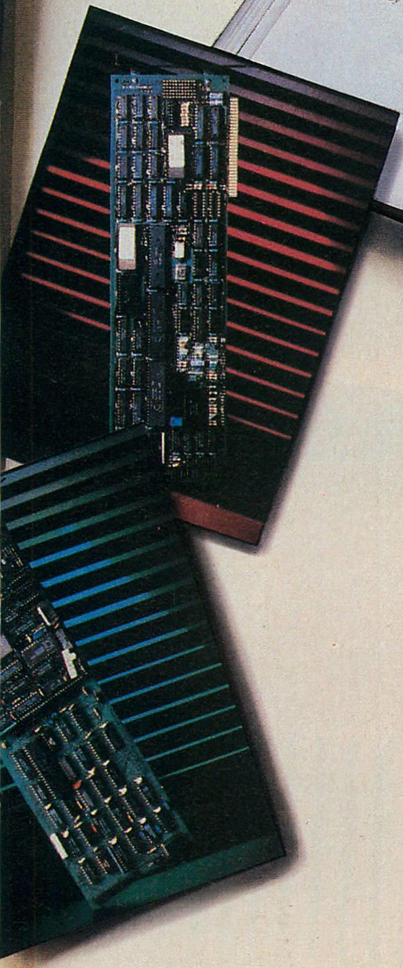

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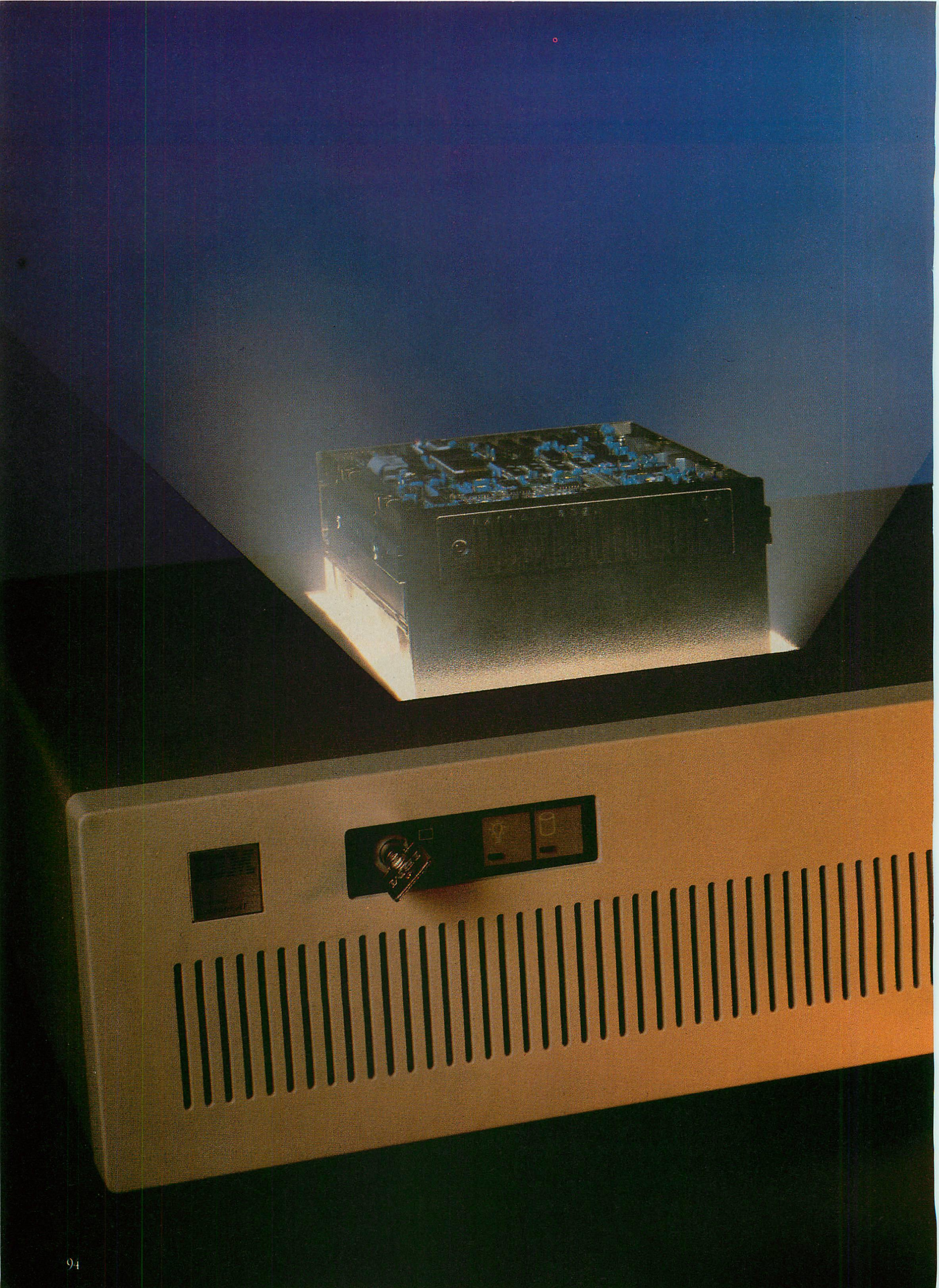

Breaking the 32MB Barrier

No more do hard-disk volumes have a 32-megabyte limit. Large disk storage systems break that barrier.

PHOTOGRAPH • MARC DAVID COHEN

Everything has its limits, and DOS is no exception. Common wisdom (and some IBM documentation) holds that DOS is limited to supporting hard-disk volumes of 32MB or less and that a single physical disk can have, at most, one active DOS partition or logical unit. This is not true in all cases.

While the 32MB limit may prevail when using standard IBM software, DOS volumes much larger than 32MB may be supported using one or more physical disks of any size.

Winchester disks with capacities greater than 32MB have been available for a while and recently have dropped in price as their use has become more popular. These disks have been supported on PCs by software that allows them to appear as multiple logical volumes, each containing up to 32MB.

This approach has its advantages. In network applications, each user has read/write access to his own volume, apart from other users. Smaller volumes offer performance advantages because directory and file allocation table searches are faster. Damage from runaway programs or user errors are more easily limited with small volumes.

For some applications, however, several smaller volumes may not be very useful. Many data management systems, for example, maintain an entire

THOMAS V. HOFFMANN

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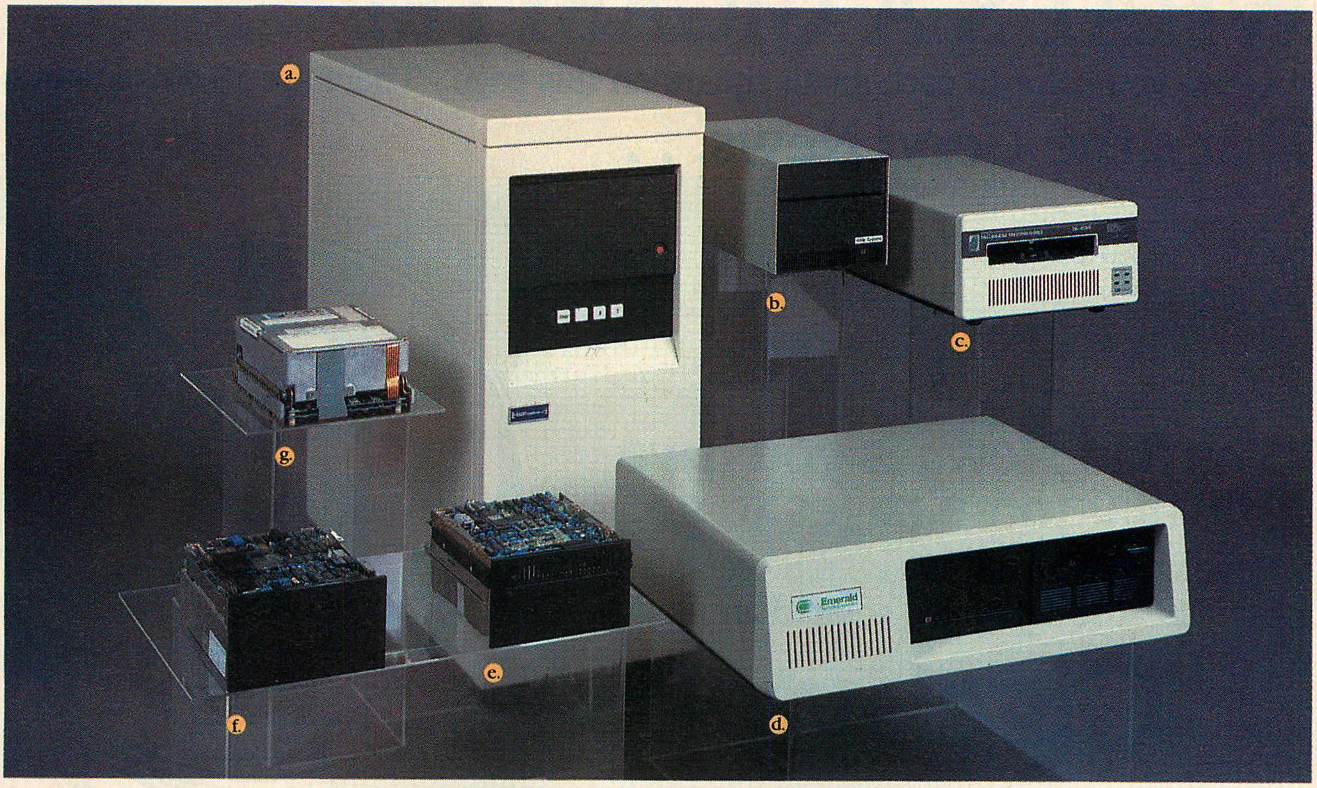

PHOTOGRAPH • CHRISTINE ARMSTRONG/BLAKESLEE-LANE

The large disk storage systems come in a variety of forms. Shown clockwise from the top (a) Racet PCMS-150, (b) GAW 65MB external drive, (c) Tallgrass TG-6180, (d) Emerald Series 4000/1 PS70, (e) Bell B86, (f) Express 72F-1, and (g) Core ATplus.

database as a single DOS file. If a DOS volume is limited to 32MB, then so is the largest file, because files cannot span multiple volumes.

Disk systems that provide software support for single volumes larger than 32MB are now available. Seven such systems, with usable capacities ranging from 55MB to 150MB, are reviewed here: B86 72MB internal hard disk, Bell Technologies Inc.; Core ATplus 72MB, Core International; Series 4000/1 PS70 59MB external drive with 60MB tape backup, Emerald Systems Corporation; 72F-1 external hard disk, Express Systems, Inc.; GAW 65MB external drive, GAW Systems; Racet PCMS-150 150MB external system, Racet Computes, Ltd.; and TG-6180 83MB external drive with tape backup, Tallgrass Technologies. Each system can be configured with multiple DOS volumes on a single physical drive, and the size of any volume (except, in a few cases, the first) can be as large as available disk space.

OUTER LIMITS

DOS is actually a very flexible system, designed to support a variety of disk sizes and formats. The apparent 32MB limit is not a built-in property of DOS, but simply the maximum volume size possible using the standard disk formats supported by IBM. Systems using other formats are subject to different limits.

This flexibility derives from the layered architecture of the PC system as a whole and of DOS in particular. A computer system can be considered as a hierarchy of layers, with human users at the top and servile hardware at the bottom. In between are many layers of software and hardware. Each layer takes abstractions from above and makes them more concrete for the layers below. Programs store information in files, which DOS organizes into volumes. Each volume has a boot sector, file allocation table (FAT), directory, and data area, all of which are structures internal to DOS. DOS uses drivers that view volumes as a series of blocks. The driver translates logical blocks into physical cylinder, head, and sector numbers for the BIOS, which in turn translates these into actual hardware commands to the physical drive mechanism.

In a well-designed system, the interfaces between various layers should be simple, with complexity confined inside the layers. For the most part, DOS follows this principle. In particular, the internal structure of directories and FATs does not need to be known outside DOS, either to the user programs above or the drivers below.

DOS uses some shared data structures to allow its various components to adapt to differences in physical and logical disk organization. The BIOS parameter block, or BPB, (see table 1) defines the physical layout of a DOS volume: sector size, cluster size, number of root directory entries, FAT size, and total volume size. DOS obtains a copy of the BPB for each volume from its drivers. The drivers, in turn, generally find a copy of the BPB (with some physical drive parameters appended) in the first sector of the disk volume, although they need not keep it there.

Most disk drives used in PCs, and all drives currently supported by IBM, use a physical sector size of 512 bytes. Because the BPB has only a 16-bit word for the total number of sectors in a logical volume, the limit for IBM format volumes seems to be $512 * (2^{16} - 1)$, or 33,553,920 bytes. This is the basis for the 32MB boundary; it is, in fact, a restriction of the volume size to no more than 65,535, or $2^{16} - 1$, sectors. The BPB, however, also contains an entry for the number of bytes per sector. Clearly, doubling the sector size doubles the volume size if the number of sectors stays the same. With maximum size sectors, volumes could grow to be more than 4.2 billion bytes.

If adjusting one word in a table were all that was required, breaking the 32MB barrier would not be difficult. Disk boundaries would not be a concern (until 4.2 gigabytes begins to seem small). Obviously there is more to it.

TABLE 1: *BIOS Parameter Block (BPB)*

OFFSET	SIZE	DESCRIPTION
BOOT CODE/OEM ID		
00H	3 bytes	DOS 2.1: 3-byte NEAR JMP (E9H,xx,xx) DOS 3.x: 2-byte SHORT JMP (EBH,xx) followed by NOP (90H)
03H	8 bytes	OEM name/version (e.g., IBM 3.1)
DOS BIOS PARAMETER BLOCK		
0BH	WORD	Sector size (bytes per sector)
0DH	BYTE	Cluster size (sector per cluster, must be a power of 2)
0EH	WORD	Reserved sectors (starting at logical sector 0, usually 1 for boot block)
10H	BYTE	Number of FATs, usually 2
11H	WORD	Number of root directory entries (32 bytes each)
13H	WORD	Total number of sectors in the logical disk image (volume)
15H	BYTE	Media descriptor (F8H for nonremovable fixed disks)
16H	WORD	FAT size (number of sectors in one FAT)
ADDITIONAL INFORMATION FOR IBM STANDARD DRIVER		
18H	WORD	Sectors per track
1AH	WORD	Number of heads (surfaces)
1CH	WORD	Number of hidden sectors (from start of disk to logical sector 0 of this volume)

The BPB is returned by block device drivers to DOS. IBM's format utility writes a BPB at the beginning of the first sector of each DOS volume. This sector is called the boot sector and the offsets given are from the beginning of the boot sector.

Suppose a user wants to handle a single volume between 64MB and 128MB, so he settles on a sector size of 2,048 bytes. The maximum sector size for most disk controllers is 1,024 bytes. Even if the controller could format larger sectors, it would not help much. The hard-disk boot code in BIOS assumes a physical sector size of 512, and larger (or smaller) sectors would fail the controller's CRC check.

Sticking with 512-byte physical sectors seems the convenient solution to the problem. What is needed are *logical* sectors made out of four physical sectors. One answer would be a loadable DOS device driver that simply *says* the sectors are 2,048 bytes long and transfers four physical sectors for each logical sector. This is, in fact, what most of the vendors of the reviewed storage systems do. Additional problems must be solved, however.

Booting from the large disk is desirable, especially if it is the only drive installed in the system. One way to accomplish this is to put at the beginning of the physical disk a small volume that can be booted with standard DOS, which then loads the special device driver from the boot volume. This is the method used by Tallgrass Technologies and Core International.

A somewhat more convenient method is to have the entire physical disk be a single large volume that can be booted, especially if it has batch files and programs containing hard-coded references to the C: drive. The Bell Technologies, Express, and GAW systems all offer a form of Vfeature Deluxe software from Golden Bow Systems, which supports a single, large, bootable volume. Emerald and Racet Computes offer their own proprietary software to provide the same function.

Emerald's approach is unique in that it does not use a loadable driver in the usual sense. Instead, Emerald replaces the entire set of standard DOS drivers, contained in the hidden system file IBMBIO.COM, with its own version. This is a somewhat daring approach, because the DOS-to-internal driver interface is not published and is subject to change. Tallgrass and the three Vfeature-equipped systems all patch the IBMBIO.COM file to effect changes. For this reason, they require DOS 3.1.

The business of patching or replacing the standard DOS drivers bears further examination. Apparently, it is not strictly necessary—neither Racet nor Core do it. Golden Bow Systems, vendor of the Vfeature Deluxe software, explained it simply changes the sector size in the IBMBIO.COM initialization code and corrects an obscure bug in the write logic. The Tallgrass patch changes a single instruction in IBMBIO.COM from one loading a value stored in a variable to one loading an immediate constant value. The patches seem to be small and manageable. The important questions for users are the efficacy and reliability of the solution.

ENVIRONMENTAL ISSUES

Peaceful coexistence is more than a geopolitical strategy of the sixties; it is what every PC user has the right to expect from system components. Whenever any component moves away from the IBM standard, this issue becomes critical. Breaking the 32MB barrier involves special considerations.

For this review, the Bell and Core systems were tested on a PC/AT, and the remaining products were tested on either a standard PC or PC/XT. All are also available in AT configurations. The Bell B86 comes *only* in a configuration for ATs and is delivered with cables and mounting hardware for internal installation as the first or second drive. The Core drive will connect to the XT's fixed-disk controller, and Core offers a controller to adapt its product to the PC for an additional $495.

The Tallgrass TG-6180 uses a host adapter that can coexist with existing hard drives on the XT. Furthermore, the Tallgrass software does not affect the original XT fixed-disk drive, so it can be added to a system full of files with no adverse effect on the original volumes. (Any system should be fully backed up before hardware components are added or removed.)

All systems except for Tallgrass use controllers that cannot coexist on the same bus with an XT-compatible controller. Some suppliers provide cables to allow connecting the original drive and the new one to the same controller. Golden Bow's Vfeature software is particularly flexible in accommodating various combinations of drives and controllers. This is to be expected, because it is sold largely to dealers who package it with a variety of systems. GAW Systems specializes in customized configurations and offers many types of drives, controllers, and custom ROM chips to make them all operate together.

Compatibility is much harder to predict in software than hardware. Well-behaved programs should not make any assumptions about sector sizes. Programs that do direct logical block transfers using DOS interrupts 25H and 26H need to know the logical sector size, which can be obtained using DOS function 1CH. IBM's *DOS Technical Reference* calls the sector-size figure returned by DOS function call 1CH the

TABLE 2: *Drive Performance*

VENDOR		BELL[a]	CORE[a]	EMERALD	EXPRESS	GAW	RACET[b]	TALLGRASS
PHYSICAL DATA								
Sector size		512	512	256	512	512	256	512
Sectors/track		17	17	17	17	17	32	20
Heads		10	9	7	11	7	8	9
Cylinders		829	923	986	753	917	1,699	912
LOGICAL DATA								
Sector size		2,048	2,048	1,024	2,048	1,024	2,048	2,048
Sectors/cluster		8	4	4	8	16	1	4
Bytes/cluster		16,536	8,192	4,096	16,536	16,536	2,048	8,192
Total file space								
Sectors		35,232	35,419	58,310	35,202	54,560	60,528	40,725
Bytes		72,155,136	72,538,112	59,709,440	72,093,696	55,869,440	123,961,344	83,404,800
DISKP TIMINGS (milliseconds)								
Track-track		4.44	4.66	3.78	12.13	6.92	3.40	5.82
Average		12.96	12.63	14.99	(346)[c] 26.96	(25) 27.02	6.64	14.17
Random		20.92	20.76	25.54	(199) 45.25	(50) 45.86	8.78	22.02
BENCHMARKS (milliseconds)								
Sequential read								
Sectors traveled:	1	25	11	19	30	27	27	11
	8	91	99	63	146	181	115	93
	16	—[d]	—	110	—	368	—	—
	24	—	—	165	—	434	—	—
Random read, 1 sector								
% of disk traveled:	10	29	30	45	59	56	41	56
	33	47	38	52	84	81	48	67
	50	45	56	70	93	88	49	73
	90	62	71	95	135	122	65	93
Random read, 8 sectors								
% of disk traveled:	10	93	382	80	176	146	124	140
	33	107	126	96	198	170	132	151
	50	118	143	115	206	176	132	157
	90	126	157	129	250	203	151	176

[a] *Tested in the AT; all others tested in the XT.*
[b] *Uses 8-inch media; all others use 5¼-inch media.*
[c] *The number of errors encountered during each timing is indicated in parentheses.*
[d] *This benchmark does not work correctly for sector sizes over 1,024 due to buffer size limitations.*

DISKP uses direct BIOS access, which does not recognize FAT bad-sector marking; performance figures reflect failed retries on bad blocks. Under DOS, bad sectors do not degrade performance. Note that timings for Bell and Core reflect AT installation.

physical sector size, but in fact it is whatever sector size is reported back by the driver for the queried volume. Once patched for larger logical sector sizes, DOS always returns the larger patched value for function call 1CH. Well-behaved programs that use 1CH should function correctly with any of the disk systems tested. In practice, however, a user will not ordinarily discover whether or not a program is well-behaved by these criteria until it fails.

During testing, some SuperLok-protected programs could not be installed for key-disk-free operation on volumes with a sector size of 2,048. The programs could be run from the large volume using the key disk, but the installation procedure, which writes hidden copy-protection information on the hard disk, failed with an error message from the install program. One less-than-perfect solution for this type of problem is to install the program files themselves on a smaller DOS volume with standard 512-byte sectors, but direct data files to the large volume. Softguard Systems, the manufacturer of SuperLok, is working on a solution to this problem. Among companies using the SuperLok form of copy protection are the Lotus Development Corporation and Ashton-Tate.

HIGH PERFORMANCE

All of the high-capacity drives performed much better than standard XT 10MB drives. This is primarily due to faster seek times. Performance was measured with the *PC Tech Journal* benchmarks ("Fixed-Disk Benchmarks," William J. Hunt, November 1984, p. 64), modified to accommodate larger sector sizes, and with the DISKP program from Core, which measures track-to-track and average seek times. The results are summarized in table 2.

The specific benchmark results may be difficult to correlate with one another, because the disk sizes and parameters differ considerably from unit to unit, and the Core and Bell systems were tested on an AT, while the others were tested on an XT.

Most disks have some bad sectors that are marked as such in the FAT and not used by DOS for file storage. When performance tests that do direct disk reads of random sectors using INT 25H encounter these bad sectors, the result-

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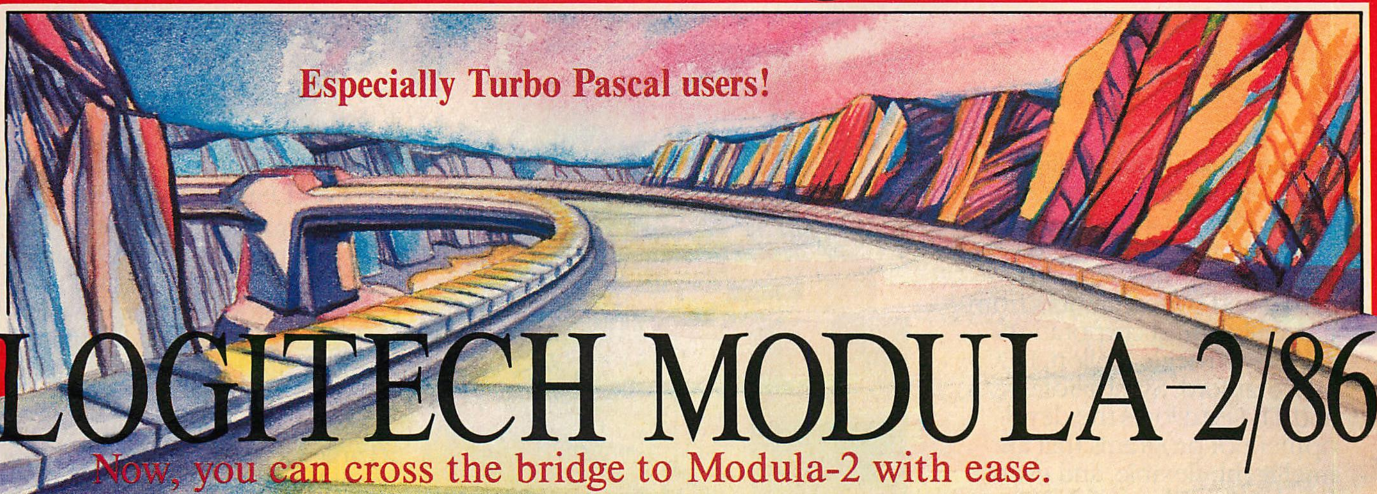

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ing retries by DOS and BIOS cause much longer access times to be reported. The number of errors encountered during each test is shown in parentheses in table 2. These errors would not occur during normal DOS file access; performance of these disks in everyday use should be better than that shown in the table.

Hardware installation for all of the systems was simple and straightforward, whether internally or externally mounted. Software installation fell into two categories: easy and not required. The easy ones (Bell, Core, Emerald, Racet, and Tallgrass) had clear and simple-to-understand programs and documentation and worked as expected.

The GAW and Express units did not require software installation because the disks came preloaded with Vfeature Deluxe and DOS 3.1. (The Bell system also provides Vfeature, but it must be installed by the user.) Preloading DOS seems to be in violation of IBM license rules preventing distribution of copies of DOS, even though only the system proper, without any utilities, was involved here. This is the reason many software packages (especially copy-protected ones) are shipped on disks with empty space reserved for the user to install the operating system.

These manufacturers are obviously trying to make the installation as painless as possible for the user. Their working disks contained DOS 3.1 and the installed version of the Vfeature software configured for the appropriate physical drive parameters. Unfortunately, no one included complete information on the drive configuration, although Express did include a disk manual that gave the cylinder and head parameters for its Fujitsu drive.

Ordinarily, users would appreciate the convenience of quick installation and set-up. But if the system needed to be set up again from scratch, some information gaps could cause real frustration. As a generic document for a variety of configurations, the Vfeature manual contains a worksheet on which to record the number of cylinders, heads, and write precompensation and reduced write current cylinders. This information is required for making the working diskette and for getting low-level formatting to work correctly, but none of the vendors supplied it.

Vfeature users should perform their own installation procedure, starting with the creation of the working diskette from the master diskette, for another very important reason: the software checks the type of disk controller in use and makes some changes to the installed programs depending on the type of controller detected. This should be done on the same controller to be used in the actual system, or at least one of the same manufacture.

When the Express disk (which had been preformatted in an AT at the factory) was installed in a PC, nothing happened. A low-level format was performed on the Express disk on the theory that it might be required due to controller differences. After nearly seven hours, which included low-level formatting, bad block entry, DOS volume formatting, and software installation, the system finally booted and reported more than 50MB of bad blocks on a 72MB disk. The working diskette, which Express so conveniently supplied, had also been created on an AT and thus embodied some false assumptions. The working disk was recreated from the master disk, using the clear and adequate instructions supplied in the Vfeature manual. The low-level and DOS formatting process had to be repeated, although it took only about 2½ hours the second time.

THE PRODUCTS

Vfeature Deluxe, the software written by Golden Bow Systems to support volumes larger than 32MB, is used with the Bell, Express, and GAW units. It supports a variety of disks with any number of cylinders and 16 surfaces using XT- or AT-compatible disk controllers (although IBM's XT controller will not support disks with more than eight surfaces). Vfeature does not depend on the default drive parameters in the controller's hard-disk BIOS, thus, any physically compatible drive and controller combination can be used.

Vfeature supports multiple logical DOS volumes on a single disk, single volumes larger than 32MB using logical sectors larger than 512 bytes, and logical volumes that span two disks.

The software provides several levels of security options. Logical volumes can be password protected from all access or just write protected. Provisions for read and write protection of diskette drives are included to prevent unauthorized export or import of programs and data. For serious diskette security, Golden Bow offers FiXT/S, a PROM option for PC and XT machines that can disable diskette booting.

The Vfeature package includes a menu-driven configuration program that allows low-level hardware formatting, drive partitioning, volume and password assignment, and DOS formatting

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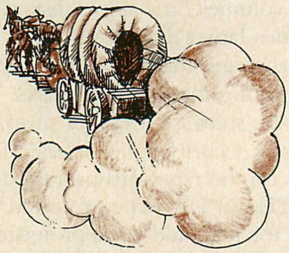

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that allows the user to control the allocation unit (cluster) size.

Users with hard disks larger than 32MB but without software support for large volumes should consider Vfeature Deluxe. It is reasonably priced at $120, with technical support available by telephone. DOS 3.1 is required.

B86 (Bell Technologies). Bell Technologies sells to the UNIX market. Its 72MB internal drive is for the AT only and comes with two different installation manuals and software sets—one for XENIX and one for DOS. A pair of ROM chips replaces the original IBM set. The ROMs, which support XENIX installations, differ from the IBM version only in the drive parameter table for drive types 7 and 8. DOS users do not need to install them, because Vfeature overrides the built-in drive parameters.

Bell provides very good installation and set-up documentation, with checklists throughout. It is complete without being massive. One very nice touch is a one-page "Read this if You Hate to Read Manuals" instruction sheet. Unfortunately, if the drive is unformatted (and Bell now ships mostly unformatted drives) the long-form installation is necessary, starting with a low-level format that takes 30 minutes for a 72MB drive. Bell uses a Toshiba drive.

Core ATplus (Core International). The Core 72MB system is intended for use with the AT and comes with a pair of ROMs that are installed in the two empty sockets in the AT system board. Older ATs may have all four ROM sockets occupied; for these systems, Core will exchange the old set for a new two-chip set of official IBM AT ROMs. (Core is an authorized IBM dealer.)

Installation instructions are brief, but adequate. One possibly confusing error involves a description of the signal cable from the hard-disk unit: the installation instructions describe the orientation of the signal cable attachment to the AT disk controller board in terms of an arrow on the connector and a blue wire; in fact, the connector has no arrow and the wire is red, not blue.

ATplus's Control Data Corporation drive is very fast and seems especially rugged. These are evidently the major advantages for which the Core unit's premium price is paid. Its disadvantage, as with other add-in internal drives for the AT, is that it leaves room for only a single flexible disk drive. The AT drive C: can be replaced with the Core unit to avoid this problem.

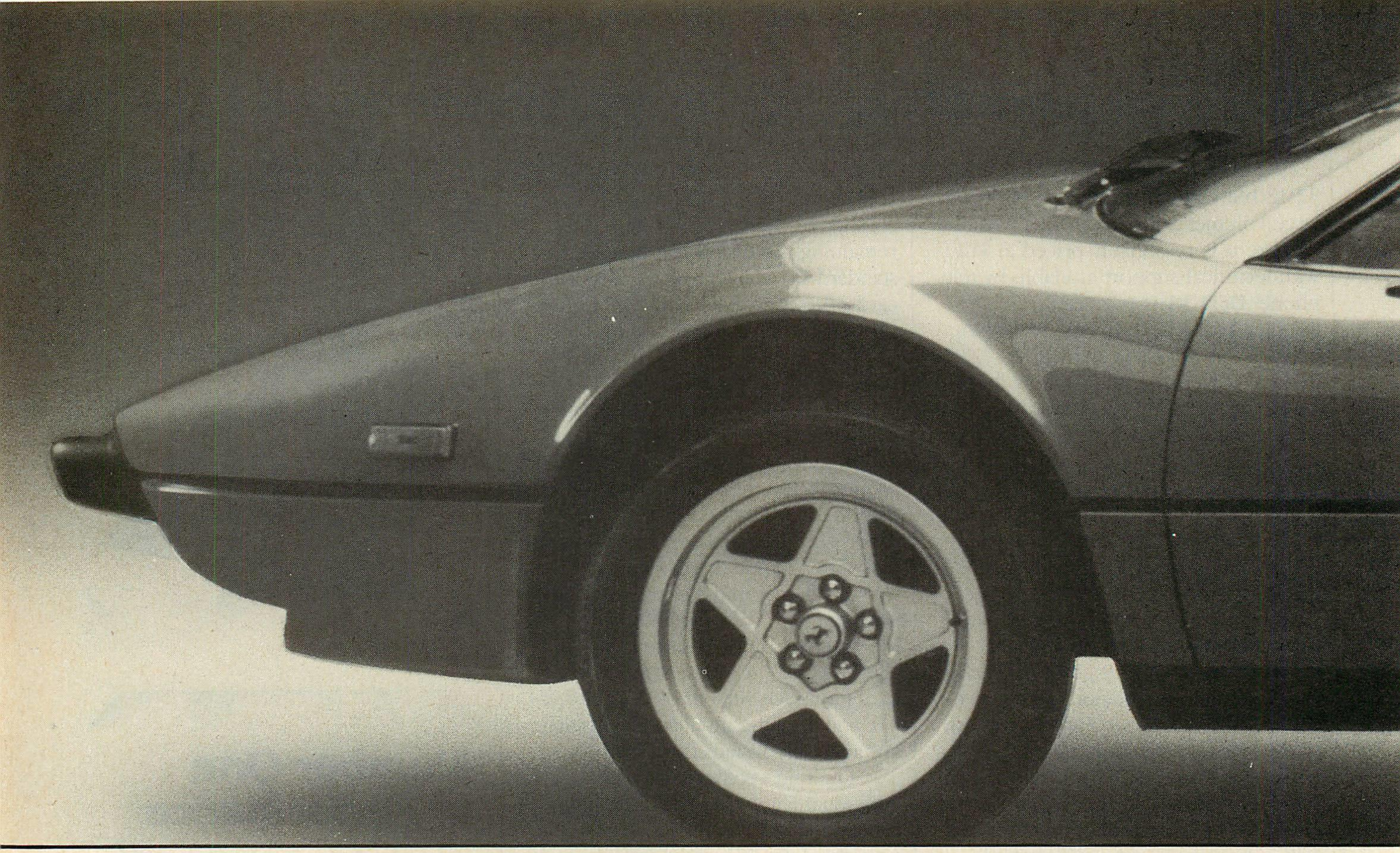
Series 4000/1 PS70 (Emerald Systems). The Emerald Series 4000 model PS70 provides 59.7MB of disk storage and a 60MB tape backup unit in a chassis the size and shape of the PC system unit. The chassis has five slots, one of which is occupied by the disk controller and another by the tape controller. The remaining three slots can be used for standard PC adapter and expansion cards; this is an especially nice feature for users with crowded systems. The Emerald system uses a Vertex drive and provides its own software.

The Emerald software installation is smooth and can be finished in about five minutes. Low-level formatting is not required. The menu-driven procedure directs the user to select the DOS volume sizes, then to insert a DOS system disk. The volume directory and FAT are initialized, then the system is copied onto the hard disk, together with the Emerald BIOS in place of the IBMBIO.COM. A different Emerald BIOS exists for each version of DOS (2.0, 2.1, 3.0, and 3.1); the installation software automatically installs the correct one.

Emerald's software provides several additional features. A sector caching function allows the user to set aside a portion of the PC's main memory to retain the contents of the most recently accessed disk blocks. On next access, the system looks first in the cache before retrieving the blocks again from the physical disk. This can significantly improve system performance in many situations where a group of sectors is repeatedly read. The difference was most apparent when switching between a word processor and a calculator program. A password-protection feature is also provided, which prevents the system from booting from the hard disk if the correct password is not supplied.

Another nice feature of the Emerald system is automatic bad track remapping. The last six cylinders of each disk surface, comprising a total of 42 tracks overall, are reserved to be used in place of tracks with manufacturing defects. The Emerald BIOS driver performs the remapping on a whole track basis. The result is that CHKDSK never reports any bad blocks until all 42 substitute tracks have been exhausted. Low-level formatting and surface analysis utilities are also provided.

72F-1 72MB kit (Express Systems). Confusing and irrelevant documentation supplied in addition to the Vfeature manual made installation of the Express Systems 72MB kit more of a trial-and-error process than it should have been. (Express said it has made a few changes to Vfeature and calls it by a different name, Coalesce.) Several of the instruction sheets referred to programs not



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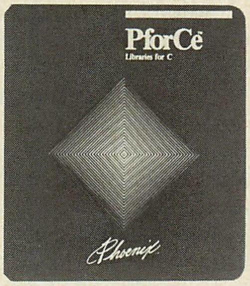

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intended to be part of the product. The typeset installation and operation manual is nothing more than the Vfeature manual with all references to Vfeature Deluxe inexplicably changed to Max Disk; however, the software diskettes themselves are still labeled Vfeature.

Adding to the confusion, the Express software displayed a menu titled Orion Computer Products, because the Express Systems disk product is manufactured by Orion under a private-label agreement.

The Fujitsu drive included with the Express unit had 48 defects, within the Fujitsu specifications for an acceptable drive, but far more than any other 72MB drive tested. When the low-level format program requested the bad block entries, it took them one at a time and spent longer and longer processing each one, starting at 16 seconds and ending at more than 3 minutes per entry. The total time spent at this process was an unpleasant 90 minutes.

Specifying write precomp was necessary, although the software never requested this information, and Express did not supply it with the system. The correct information was immediately available from telephone support.

Once the installation was complete, the Fujitsu drive worked as advertised. Fujitsu has an excellent reputation as a disk drive manufacturer. Express was the only vendor to supply the drive manufacturer's technical documentation.

GAW 65MB external drive (GAW Systems). The GAW unit is a compact external chassis for the XT, measuring 5-by-6-by-12½ inches and incorporating room for three half-height 5¼-inch form factor storage devices. The full-height Maxtor drive occupies two positions, leaving a vacant position for a backup tape drive or additional hard disk. The Xebec controller is cabled for two disks, and the power supply has adequate additional capacity for any half-height drive.

The only documentation supplied with the unit is the Vfeature manual, but the disk is preloaded and ready to run. No low-level formatting is necessary. GAW Systems claims that it has experience with many drive and controller combinations and offers custom configurations, cabling, and controller board BIOS ROMs.

This particular configuration is being phased out in favor of a 72MB unit in an identical cabinet for $2,895.

Racet PCMS-150 (Racet Computes Ltd.). Racet's systems are unique in several respects—most obviously size and capacity. The disks are housed in a large, wheeled, freestanding metal cabinet measuring 28 by 11 by 28 inches; the whole assembly weighs in excess of 80 pounds and requires two people for unpacking. Racet supplies disk systems ranging from 150MB to 411MB per disk in the same size cabinet and even offers a fault-tolerant version, with redundant power supplies and dual disks, plus software that automatically duplicates data written to one volume on another of the same size. Each system is available with a 150MB tape backup that uses a 24-track, serpentine self-threading spool. This is a high-reliability, industrial-strength mass storage system.

The system tested was the PCMS-150, with a total formatted capacity of 162MB. The unit included the streaming tape drive with a formatted capacity of 150MB and an eight-inch Pertec drive and proprietary controller.

The Racet software allows many more volumes to be defined on the disk than are active. Volumes are activated by attaching them to a particular drive letter. This can be done dynamically while the system is running. Racet also supports reconfiguring of partitions, by splitting one or joining two adjacent ones, without affecting other partitions on the disk. All data in the affected partitions, however, are lost.

Racet has been in the hard-disk add-on business since 1977 (it started out providing disks and supporting software for Radio Shack computers), and its experience shows. The installation and user documentation is extremely thorough and professional. Racet has particular experience in providing large disk systems for use as network file servers, and its software and documentation provide many specific features and hints for network installation.

TG-6180 (Tallgrass Technologies). The TG-6180 is an external unit with an integral 60MB cartridge tape backup. The chassis measures 5½-by-10-by-17 inches. The installation manual is detailed, well-organized, and includes an index. The step-by-step software operating instructions are clear, although the screen examples in the documentation sometimes vary from the actual screens displayed by the software.

The Tallgrass configuration requires a small volume with IBM standard 512-byte sectors for booting. The remaining 83MB can be a single, large volume or can be divided into as many as 15 smaller volumes. Large-volume support is provided via a program called TGPSEC, instructions for which are contained in files on the software release diskette. These disk-based instructions are the only mention of

large-volume support; nothing is said in the hard-copy manual. TGPSEC is to be run after creating the disk partitions and logical volumes and before formatting the volumes.

DIFFERENCES WORTH NOTING

While all of these systems break the 32MB barrier, they fall naturally into distinct groups, with price, capacity, and features fairly well correlated.

The Racet system, at $16,500, is in a class by itself, by virtue of physical size, total capacity (up to 822MB), and the provision for automatic redundant volumes for critical data. This system is appropriate for large network and database applications and where expansion capability and fault tolerance are more important than price per megabyte.

In the $7,500 bracket, the Tallgrass and Emerald systems offer external cabinets with disks and integrated 60MB tape backup units. Emerald's disk is smaller, but noticeably faster, and the cabinet doubles as an expansion unit for additional adapter cards.

The Bell, Core, and Express systems, ranging in price from $1,800 to $4,600, are all 72MB internally mounted drives, ideal for desktop XTs or ATs. Core claims extraordinary ruggedness and reliability for its drives, which are specially adapted by Core; they also command a premium price. The lower-priced Express disk has the most bad sectors and slowest performance of all the units tested.

The 55MB formatted GAW drive is the smallest of the drives tested. Its external cabinet has room for another half-height device, and it may be favored by users owning PCs with small power supplies. Sadly, the unit tested is being discontinued due to an unreliable supply of the drive mechanism. GAW now offers a similar external subsystem with 72MB capacity for $2,895. Given that the price includes an external cabinet and power supply, the GAW units are quite competitive with the internal systems from Bell and Express.

Future versions of DOS undoubtedly will support disks much larger than these; until then, these systems offer working solutions for users who need large DOS volumes now. As the architects of DOS have learned, saying *never* is unwise when considering how soon an arbitrary system limitation will become intolerable. Whenever a barrier comes up against a legitimate user need, the barrier will always fall.

Thomas V. Hoffmann is director of advanced systems development for General Instrument.

The vendors listed below each offer a variety of models, configurations, and capacities. The pricing given here is for the specific product reviewed.

Vfeature Deluxe: $120
Golden Bow Systems
P.O. Box 3039
San Diego, CA 92103
619/298-9349
CIRCLE 345 ON READER SERVICE CARD

B86 internal hard disk: $1,995
Bell Technologies Inc.
44846 Osgood Road
Fremont, CA 94539
415/659-9097
CIRCLE 346 ON READER SERVICE CARD

Core ATplus: $4,595
Core International
7171 North Federal Highway
Boca Raton, FL 33431
305/997-6044
CIRCLE 347 ON READER SERVICE CARD

Emerald Series 4000/1 PS70: $7,510
Emerald Systems Corporation
4757 Morena Blvd.
San Diego, CA 92117
619/270-1994
CIRCLE 348 ON READER SERVICE CARD

Express 72F-1 external hard-disk system: $1,795
Express Systems, Inc.
1254½ Remington Road
Schaumburg, IL 60195
800/341-7549, ext. 3000;
312/882-7733
CIRCLE 349 ON READER SERVICE CARD

GAW 65MB external drive: $2,695
GAW Systems
6160 Lusk Blvd., Suite C205
San Diego, CA 92121
619/457-2245
CIRCLE 350 ON READER SERVICE CARD

Racet PCMS-150 external system: $16,500
Racet Computes, Ltd.
1855 W. Katella, Suite 255
Orange, CA 92667
714/997-4950
CIRCLE 351 ON READER SERVICE CARD

TG-6180 83MB external drive with tape backup: $7,495
Tallgrass Technologies
11100 W. 82nd Street
Overland Park, KS 66214
800/228-DISK;
913/492-6002
CIRCLE 352 ON READER SERVICE CARD

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IBM PC BIOS Interface Access: Gets basic I/O services in ROM BIOS not available from the operating system to get and set keyboard modes, printer port status, video attributes and cursor positioning.
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Product Code: S0200 — PC Brand: **$109.00**
List Price: **$150.00**

GREENLEAF FUNCTIONS

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32 DOS extensions: file and directory manipulation for DOS 1.1 and 2.0.
23 Screen Functions: Select mode, page, monochrome or color, palette; cursor shape, positioning; clearing and scrolling; pixel get and put; read light pen.
60 String Functions: Manipulation of strings including center and justify; efficient list operations which add, delete, and sort pointers to strings for top speed.
50 Graphics Functions: Primitives to access all graphics; typeface, formatting, and forms control.
Plus keyboard status and function key assignment, time and date algorithms . . .we could go on!

Product Code: S0770 — PC Brand: **$139.00**
List Price: **$185.00**

GREENLEAF COMMUNICATIONS

Want your application to communicate with other users or remote date bases? Now you can build asynchronous communications right into your C programs!
Over 60 functions *and demo programs in both C and assembler source code* set up an interrupt driven scheme with separate transmit and receive ring buffers for an arbitrary number of ports. Interrupt control means you can download a record, then halt the incoming stream to file it, display it, let the user tamper with it, send it back up line. Goodbye separate communications software.
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Its 80-page manual has examples of each function and guides you through asynchronous communications.

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C-SPRITE
Lattice's Debugger for Lattice C

We once called it a symbolic debugger, but Lattice® advances now bring your source code on screen for your viewing pleasure. Hand this versatile companion to your compiler a .COM or .EXE file and C-Sprite™'s source mode will display your original program statements during most operations — your function names, your variable names, your data types, and the line numbers from your source code. At any breakpoint you can disassemble the object code and see source and assembler intermingled on screen.
If inclined, you can as well view machine addresses and machine-coded instructions to scrutinize what the compiler (or an assembler) contrived. You can work with data in hex, of course, or specify C's data types to cause the debugger to display memory addresses as strings, long integers, etc., even pointers.
C-Sprite can set breakpoints using symbols or addresses. You can submit clusters of commands to be executed at the breakpoints, or set commands that execute until a condition is met. New features permit redirection of STDIN and STDOUT, display and alteration of 8087 status, the setting of pointer sizes, and a symbol table exceeding 64k.
C-Sprite even has macros. Use your source code variable names in a macro to dump the contents of entire C structures, for example. And you can debug through one of the COM ports with a second terminal so as not to disturb your program's display screen. What's more, if you link with Plink86, C-Sprite can even tackle overlays.

Product Code: L2300 — PC Brand: **$149.00**
List Price: **$175.00**

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Translates BASIC Programs Into C

For a trifling price, BASTOC™ will move truckloads of BASIC code over to C. It is a translator which takes in Microsoft Extended or CBASIC and emits pure Kernighan & Ritchie C for the Lattice compiler. It will optionally convert your program into a single monolithic C function or will decompose it into separate functions, one for each GOSUB label.
Version 2.0 adds optimization, with dramatic reductions in execution time. It converts to C integers those numeric variables it finds in BASIC programs which really do not need floating point. It eliminates unreachable code. Where BASIC uses full assignment statements to increment and decrement counter, BASTOC converts to C's compact form, nested in other statements. Strings are dynamically allocated in the target program, ridding your application of BASIC's catatonic halts for garbage collection.
BASTOC will try to create structure of even the most convoluted BASIC code, and writes any indigestible statement into the C output as a comment accompanied by an explanation of the problem. Also, you can optionally tell BASTOC to insert BASIC source lines into the C target as comments, a dandy way to learn the differences between the languages.

Ask for: S0375 & BASIC — PC Brand: **$399**
List: **$495**

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The newest version of this premier programming tool lets you layer your screen designs with up to ten overlapping images, making it easy to background a screen with pop-up lists, help boxes, and alternate sets of input fields.
Writing your own screenware is a good way to blow completion dates and profits. Panel™ works with you interactively to set up foolproof screen displays and data entry forms rapidly. It tests your form to prove that it (and test data) behave correctly, then converts the finished work into C source code for incorporation into your application. Compile with Lattice or Microsoft.
Wonderfully diverse attributes may be selected for any field — size, data type, color, of course, but also conversion of input to upper case; clearance of existing data when new entry is started; masks for standard formats (eg, dates, phone numbers); a choice of styles for numeric fields; phrases which fill in when their first letter is typed; multiple-choice lists from which to choose a field fill-in by cursoring a highlighted bar. Fields may be multi-lined (eg, name and address as one field) and scrolled if larger than the screen space allotted them.
Panel builds in a user interface for keystroke movement within and between fields, and supplies extensive validation routines for checking user field entries — in source code, so you can tack on your own unique variants. Screen designs may be dynamically loaded from file, or compiled into a program, and version 6 has optimized code to quicken display speed.
The whole package is wrapped in a monitor and keyboard customization package to tailor your application for other equipment. Panel. A superior productivity tool now bigger than ever.

Product Code: S0400,* — PC Brand: **$229.00**
List Price: **$295.00**

BTRIEVE
VERSION 4.0!
Queen-B File Manager Abdicates Royalties

This queen of b-tree file managers was unapproachable to programmers for whom royalties would ruin profit margins. So it's quite a ukase indeed that one need no longer pay a tithe to incorporate Btrieve™ in applications.
Now there is version 4.0, which hugely speeds DOS interaction, especially for large files with multiple keys. It also adds support for variable length records of virtually any length. Other new features: a read after write option to verify accuracy, useful in gritty environments like manufacturing floors; file password to deny unauthorized access or read only; and data encryption to assure network privacy.
Btrieve's foundation is a balanced-tree indexing scheme, conceded to be the fastest search technique devised (it will find any key in a million-plus item index in four or less accesses). Btrieve takes complete charge of all file creation, indexing, reading, writing, insertion, deletion, space recapture, and forward and backward searching based on full or partial keys. It builds commands right into the language you use in the form of functions you call to tell Btrieve what to do.
Btrieve has mainframe specifications! A single file may have up to 24 indexes. Segments of keys may be indexed. Each index can independently accept or block duplicate keys. Fixed record lengths can be up to 4090 characters; variable length records 64k; indexes 255 characters; files up to 4 billion bytes. It can even extend a file across two drives—even two hard disks!
Interfaces to C, Pascal, BASIC, and COBOL with single purchase; sample programs in all four languages.
The network version works with any network that supports the MS-DOS 3.1 file sharing function.

Ask for:		List Price:	PC Brand:
S0650		$245	$199
S0652	Network Version	$595	$529

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Plink86™ long the overlord of overlay linkers, now has a Plus version. As a linker Plink can be used with any compiled language which delivers Microsoft/Intel format object files. It yields automatic symbol tables and more memory maps than DOS LINK, but its overlay power has won its reputation as a miracle worker.
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Plink, the programmer's choice even when CP/M™ was the poobah of computing.

Code:	Product:	List Price:	PC Brand:
S0500	Plink86	$395	$289
S0499	Plink86-Plus	$495	$359

BASIC_C
Use Your Knowledge of BASIC to Learn C

If you're getting the message that switching from BASIC to C would be prudent, you're about to discover that it's back to basics of a different sort. BASIC is fat with hidden functions that stripped down C just doesn't have.
Gone are all those handy string manipulators like LEFT$, MID$, STRING$, etc. In C, when you reach for even simple invocations like INPUT or PRINT — well, underlying such expressions in BASIC are bulging macros which C cannot have if it is to keep its slim profile.
But now comes BASIC_C and all your old favorites are back. Over 80 routines to open and close files, field and perform conversions on file buffers, peek and poke, print using, clear screen, "instr", on error goto. . .they're all there. Some have reworked names and syntax to suit C, but all are written as one-to-one functional equivalents to the familiar features of BASIC. And they are documented one to a page in alphabetical sequence like the Microsoft manual for added familiarity.
So with BASIC_C, when you're thinking INPUT, go ahead. Use it. Or LPRINT or LOCATE or INKEY. But without BASIC_C, you will find that every line of code plunges you back in the C texts to figure out how to write it. Someday you'll want to, but for now, BASIC_C will start you programming quickly at the statement level so that you can concentrate on C's larger concepts.

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Finding Disk Parameters

While the details of most DOS functions are hidden from the user, they are not inaccessible. Disk parameters and system information are there for the asking.

GLENN F. ROBERTS

One of the most important functions of a disk operating system is to provide a standard programming interface for peripheral I/O and storage devices—principally, disk drives. DOS stores and retrieves disk information in the form of files. For most applications, file-oriented storage is extremely convenient because the details of space allocation on the disk are handled in a manner invisible to the user. For many system support functions, however, the user needs to access some of the low-level disk information that DOS maintains. This information takes two forms: parameters maintained internally by DOS that describe certain characteristics of the disk and disk storage; and special sectors, such as the root directory and file allocation table (FAT), maintained by DOS on the disk for storing system information.

The documented function calls in DOS (accessed through software interrupt 21H) for the most part provide only file-oriented access to information on disk storage devices. A method for reading and writing disk data on a logical sector basis is provided (via software interrupts 25H and 26H), but no standardized method exists for determining the size and location of important disk components such as the root directory and the FAT. Some of the ways that are used (interpreting the media descriptor byte, for example) may fail when used on devices with unusual formats, such as software-emulated disks (RAM disks), or when support for new devices is added to DOS.

Obtaining most of the information needed to write disk-based utilities that should work for all disk types is possible with some effort, however. Some of the methods to do so are poorly documented—or essentially undocumented.

DOS DISK STRUCTURE

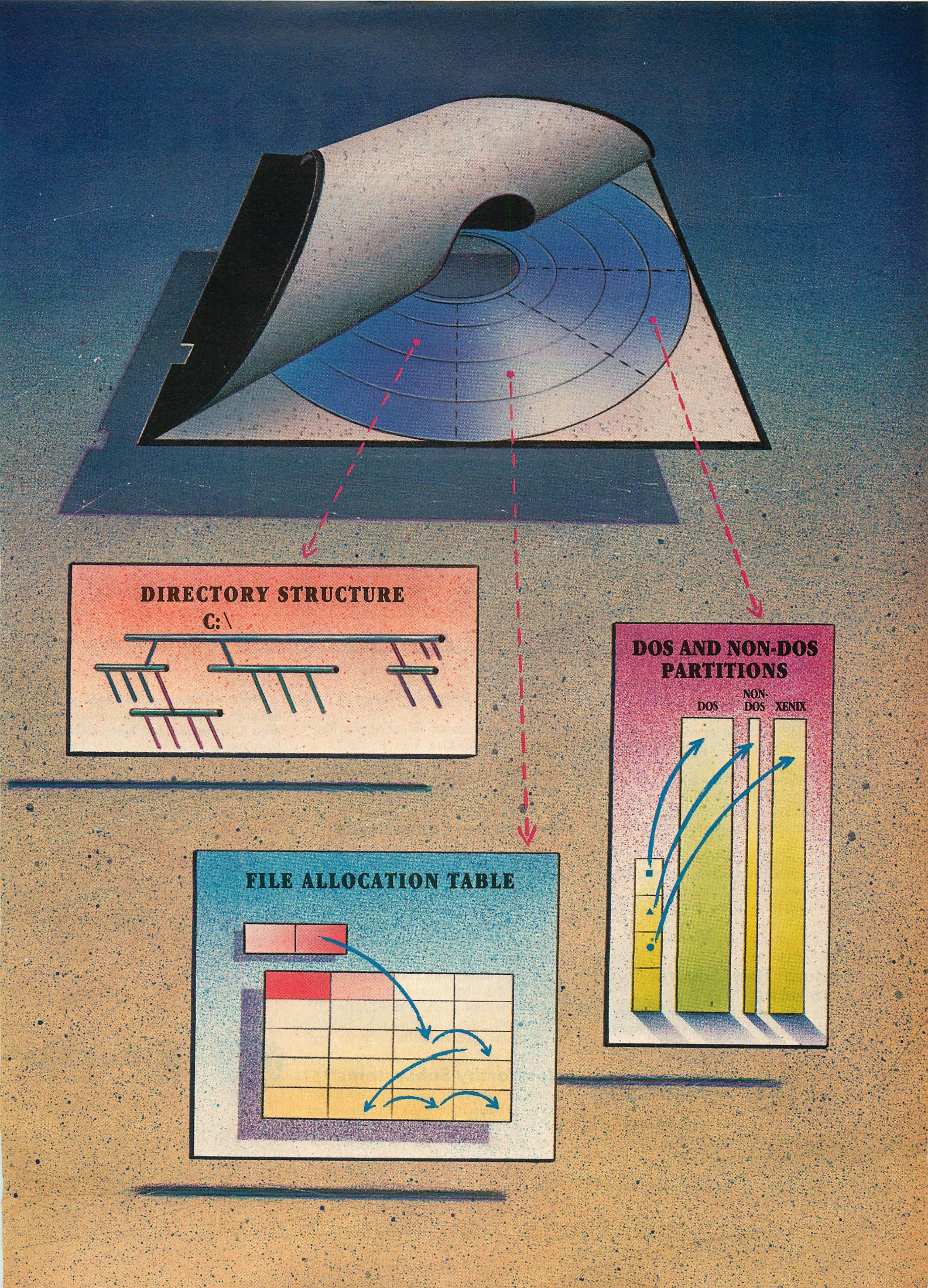
DOS views a disk volume as a logical entity that consists of a series of sequential sectors. The DOS view of a disk should be considered a logical view because the physical characteristics of the underlying medium are largely hidden from the user. These characteristics include the number of heads on the drive (or the number of recording surfaces on the medium), the number of tracks on the disk, and the number of sectors per track.

In addition to hiding the physical characteristics of the drive, DOS hides information on the partitioning of hard disks. Partitions are used to allocate a portion of a hard disk to be used as a logical drive, with more than one logical DOS drive possible on a single physical disk; or they can be used to hide a portion of a hard disk from DOS. Such hidden portions are typically used to support more than one operating system on the same disk.

DOS disks are organized into four basic areas: the boot record, the FAT area, the root directory, and the data area. These areas always occur in this order, but the amount of space allocated to each one varies.

The boot record is typically one sector in length and contains a program that the computer executes when

ILLUSTRATION • AKIO MATSUYOSHI


DIRECTORY STRUCTURE
C:\
DOS AND NON-DOS PARTITIONS
DOS
NON-DOS
XENIX
FILE ALLOCATION TABLE

booted from the disk. For bootable disks this program bootstraps DOS by loading the appropriate BIOS extension and DOS core software and then executing COMMAND.COM (or other user-specified shell). Beginning with DOS 2.0 the boot record header also has been used to store information about the disk itself. The layout of this header information is shown in figure 1.

FIGURE 1: *Format of the DOS Boot Record Header*

Offset	Type	Field	Description
0			Three-byte jump to boot code
3			Eight-byte OEM name and version
11	WORD	BPS	Bytes per sector
13	BYTE	SPC	Sectors per cluster
14	WORD	RS	Reserved sectors
16	BYTE	CF	Copies of FAT
17	WORD	D	Maximum directory entries
19	WORD	TS	Total sectors in logical image
21	BYTE	MD	Media descriptor
22	WORD	SPF	Sectors in FAT
24	WORD	SPT	Sectors per track
26	WORD	NH	Number of heads
28	WORD	HS	Hidden sectors

This format for the boot record header was not supported by IBM prior to DOS 2.0; nor is it supported by some non-IBM DOS vendors even for 2.0 and later.

The root directory, FAT, and data areas are used by DOS for maintaining files on the disk. DOS manages file space in groups of one or more sectors called *allocation units* or *clusters*. At the time that a file is created it is initially given one cluster of space. The operating system allocates physical space on the disk only in multiples of one cluster. The actual number of data bytes in the file is maintained in the file's directory entry and is displayed by using the DIR command.

The size of a cluster varies across different types and sizes of disks. On a double-sided 5¼-inch floppy disk a cluster is typically two sectors (1,024 bytes); on a 1.2MB high-density 5¼-inch floppy disk it is one sector (512 bytes); and on hard disks it can be four, eight, or even sixteen sectors. The concept of allocating space in units of more than one sector leads to a waste of disk space. A file containing just a few bytes of data will, in effect, take up 4KB (one cluster) of space on a typical 10MB hard disk. The cluster approach is nonetheless efficient in managing disk space.

DOS uses the FAT to keep track of which clusters are available on the disk, which ones are in use by files and subdirectories, and which ones are not usable (typically because of physical damage to the disk). The FAT is simply a table containing one entry for each cluster on the disk. It can have entries that are either 12- or 16-bit numbers. DOS uses a 16-bit FAT only when it must support more than 4,086 clusters on the disk (for hard disks larger than 16MB). The 4,086 figure is derived from the largest binary number expressible in 12 bits (4,096) minus the number of reserved FAT entries.

The FAT is always stored immediately following the boot record. Most disk formats store two copies of the FAT, one right after the other. This is not a DOS requirement, however, and some disks (typically RAM disks) store and maintain only one FAT copy.

DOS views the data area of a disk as a sequence of clusters, beginning with cluster 2. There is no cluster 0 or 1 because the first two entries in the FAT have other functions: FAT entry 0 contains the media descriptor, and entry 1 seems to be reserved for future use, with a constant value of FFFH (FFFFH for 16-bit FATs). Cluster 2 always resides immediately after the root directory on a disk. Partial clusters cannot exist, so if the number of sectors in the data area of a disk is not evenly divisible by the number of sectors in a cluster, unused (and unusable) sectors will appear at the end of the disk.

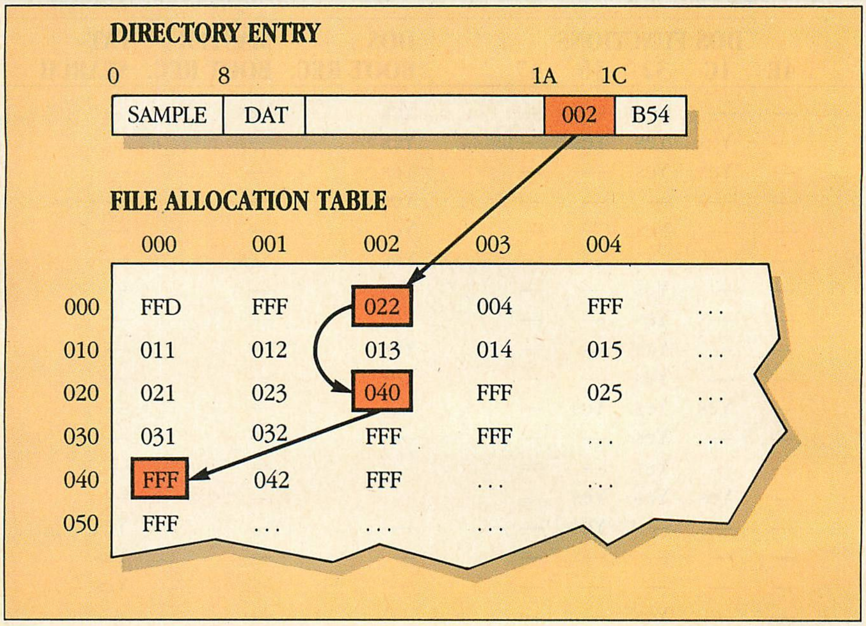
In DOS a given cluster can be in one of three states at any time: (1) it can be unused and therefore available for use by a new or expanded file; (2) it can be locked out, in which case DOS will never try to use it; or (3) it can be part of an existing file, so that DOS must either keep track of the next cluster in the file or indicate that this is the last cluster in the file.

DOS monitors all three states via the entries in the FAT. Entries of 0 indicate unused clusters. Entries of FF7H (or FFF7H for 16-bit FATs) mean that these clusters are locked out. Nonzero entries less than this are used to indicate the chaining of clusters, with FFFH (or FFFFH for 16-bit FATs) used to mark the end of the chain. The number of the first cluster in the chain is maintained in the file's directory entry.

The process of tracing a file's chain within the FAT is simple. If the file is of zero length, the cluster number in the directory entry should be 0, meaning that no clusters are reserved for the file. If the length of the file is greater than 0 but less than the cluster size, then the file requires only one cluster of space and this cluster number is given in the file's directory entry. The corresponding value in the FAT for that cluster shows the end-of-chain value. If the file requires more than one cluster for storage, the first cluster number again is given in the directory entry; however, the FAT entry for this cluster contains the number of the *next* cluster in the chain. The chaining of succeeding clusters is handled in the same manner. This process can be used to represent files of arbitrary length, with the end-of-chain value always FFFH for 12-bit FATs or FFFFH for 16-bit FATs.

Figure 2 illustrates a short cluster chain on a 360KB floppy disk with 12-bit FAT entries. The directory entry shows a file size of 2,900 bytes (B54H) for file SAMPLE.DAT. This quantity of space requires three 1KB clusters of allocated space. The chain begins with cluster 002H, as indicated by the number in the directory entry. At location

FIGURE 2: *A FAT Chain*



The FAT chain begins with the first cluster number in the directory entry, and ends with a value of FFFH for 12-bit FATs, and FFFFH for 16-bit FATs.

002H in the FAT is the number of the next cluster in the chain, 022H. At location 022H is the number of the next cluster, 040H. The FAT entry at 040H is FFFH, indicating the end of the chain.

A FEW DISK PARAMETERS

A list of useful disk parameters maintained by DOS is presented in table 1 and described below. The parameters are grouped into three categories. Those included in the first category define the physical characteristics of the disk as well as the disk drive:

TS (total sectors on the disk). This is the number of sectors in the *logical image* of the disk. It does not include portions not visible to DOS, such as the master boot record or other partitions.

BPS (bytes per sector). The size of a disk sector is usually 512 bytes; it is often smaller for software-emulated disks (RAM disks) or larger for high-capacity (more than 32MB) hard disks. (See "Breaking the 32MB Barrier," Thomas V. Hoffmann, this issue, p. 94).

MD (media descriptor). A byte providing a limited description of the type of disk medium associated with a drive is called an MD. The IBM *DOS Technical Reference* defines the bit settings in this byte as follows: bit 0, 1 = two-sided and 0 = not two-sided; bit 1, 1 = eight-sector and 0 = not eight-sector; bit 2, 1 = removable and 0 = not removable; bits 3-7 must be set to 1.

SPT (sectors per track). This is the number of sectors per physical track.

NH (number of heads). The number of read/write heads on the drive is equivalent to the number of recording surfaces available on the disk and, therefore, the number of tracks per cylinder.

HS (hidden sectors). A number of sectors are *hidden* from DOS in that they precede the DOS logical image on the physical disk. This includes the master boot record and any partitions that occupy sectors occurring prior to the DOS partition. An identical figure is given for each partition in the master boot record partition table. The *DOS Technical Reference* calls this table entry *rel sect*, which is the sector number at which each partition begins.

The second category of disk parameters consists of information relating to the way DOS organizes disk storage:

RS (reserved sectors). This is the number of sectors reserved at the beginning of the disk for the DOS boot code, which is typically one sector.

D (root directory entries). D indicates the maximum number of entries that can be stored in the root directory. Because the root directory is a fixed length (unlike subdirectories, which are essentially files), it is able to store only a fixed number of entries.

CF (copies of FAT). DOS maintains copies of the FAT on the disk. For magnetic media the CF is usually two; for RAM disks, one copy is stored.

SPF (sectors per FAT). This is the number of sectors used for each copy of the FAT that is stored on the disk.

SPC (sectors per cluster). SPC is the number of sectors in a cluster.

FUS (first usable sector). The first sector of the DOS storage area on the disk begins immediately after the end of the root directory storage area.

FDS (first directory sector). This is the first sector of the disk's root directory.

TCC (total cluster count). TCC is the total number of clusters in the data storage area of the disk.

DFS (disk free space). This is the number of clusters that are available for storage of files and/or subdirectories.

DBS (disk bad space). This is the number of clusters locked out by DOS. Clusters are typically locked out when the disk is formatted, because one or more sectors in the cluster are damaged. However, the RECOVER utility also can lock out clusters on disks that have developed bad sectors over time.

DUS (disk used space). This is the number of clusters in use by files and subdirectories. DUS plus DBS plus DFS should be equal to TCC.

The third category of parameters is a miscellaneous collection of information on disk usage and characteristics:

DDA (device driver address). DDA is a far address (offset and segment) pointing to the header of the DOS device driver for the drive (descriptions of the driver and header layouts can be found in the *DOS Technical Reference*).

CWD (current working directory). The current working directory for the drive is set by the DOS CD command or CHDIR function (function 3B).

DVN (disk volume name). The 11-character volume name is assigned to the disk when it is formatted or via the DOS LABEL command (3.0 and later).

DCD (disk creation date). This is the date on which the disk was formatted.

DCT (disk creation time). This is the time at which the disk was formatted.

OEM (original equipment manufacturer). The OEM is an eight-byte string indicating the DOS version and distribution used to format the disk.

OBTAINING DISK INFORMATION

Some utilities may require that a number of different techniques be used to obtain all of the information needed for a disk or drive. Table 1 summarizes ways in which the various disk parameters discussed above may be obtained.

The easiest and safest means (in terms of transportability across DOS implementations and versions) of getting disk information are documented DOS function calls. The DOS function call 1BH and the related call 1CH return bytes per sector (BPS), sectors per clus-

TABLE 1: *Disk Information Sources*

PARAMETER	DESCRIPTION	DOS FUNCTIONS 4E	1C	32	36	47	DOS BOOT REC.	MASTER BOOT REC.	FAT SEARCH
TS	Total sectors on disk	—	—	—	—	—	Yes	Yes	—
BPS	Bytes per sector	—	Yes	Yes	Yes	—	Yes	—	—
MD	Media descriptor	—	Yes	Yes	—	—	Yes	—	—
SPT	Sectors per track	—	—	—	—	—	Yes	—	—
NH	Number of heads	—	—	Yes	—	—	Yes	—	—
HS	Sectors hidden from DOS	—	—	—	—	—	Yes	Yes	—
RS	Reserved sectors	—	—	Yes	—	—	Yes	—	—
D	Root directory entries	—	—	Yes	—	—	Yes	—	—
CF	Copies of FAT	—	—	Yes	—	—	Yes	—	—
SPF	Sectors in FAT	—	—	Yes	—	—	Yes	—	—
SPC	Sectors per cluster	—	Yes	Yes	Yes	—	Yes	—	—
FUS	First usable sector	—	—	Yes	—	—	—	—	—
FDS	First directory sector	—	—	Yes	—	—	—	—	—
TCC	Total cluster count	—	Yes	Yes	Yes	—	—	—	—
DFS	Disk free space	—	—	—	Yes	—	—	—	Yes
DBS	Disk bad space	—	—	—	—	—	—	—	Yes
DUS	Disk used space	—	—	—	—	—	—	—	Yes
DDA	Device driver address	—	—	Yes	—	—	—	—	—
CWD	Current working directory	—	—	Yes	—	Yes	—	—	—
DVN	Disk volume name	Yes	—	—	—	—	—	—	—
DCD	Disk creation date	Yes	—	—	—	—	—	—	—
DCT	Disk creation time	Yes	—	—	—	—	—	—	—
OEM	Eight-byte OEM name	—	—	—	—	—	Yes	—	—
AD	Assigned disk	—	—	Yes	—	—	—	—	—

An important point to remember is that DOS function 32H is undocumented and, therefore, is subject to change or even abandonment. Furthermore, the format of the DOS boot record is not standard across all DOS versions and vendors.

ter (SPC), total cluster count (TCC), and the media descriptor (MD). (Call 1BH queries the default drive, and call 1CH queries a specified drive.) One common use of both function calls is to determine the number of sectors occupied by each copy of the FAT. Sectors per FAT are calculated as follows:

SPF = ((TCC + 2) * BPC) / BPS

where BPC is the number of bytes per cluster in the FAT. DOS uses a BPC value of 3/2 (1.5 bytes or 12 bits per FAT entry) whenever it can, but beginning with DOS 3.0, support is provided for 2-byte FAT entries (BPC = 2). The *DOS Technical Reference* gives the following rule for determining BPC: BPC = 1.5 if TCC+2 is less than or equal to 4,086; BPC = 2 if TCC+2 is greater than 4,086.

The largest legal FAT value is 4,086 (0FF6H), because any higher values (0FF7H-0FFFH) indicate bad clusters and other special conditions. The *DOS Technical Reference* claims to reserve cluster values FF0H-FF6H, but does not explain what they are used for.

If a remainder is left in calculating SPF, the result must be rounded up to the next integer. The integer 2 is added to TCC in this calculation because the number of entries in the FAT is two more than TCC (the first two FAT entries are reserved for storage of the media descriptor information).

When SPF is known, the absolute sector read interrupt (25H) can be used to read the FAT by assuming that the FAT starts at logical sector 1 (that is, only one sector is used by the DOS boot record or, equivalently, that RS = 1). This is a safe approach; however it may not work if DOS is ever implemented to accommodate boot records of more than one sector.

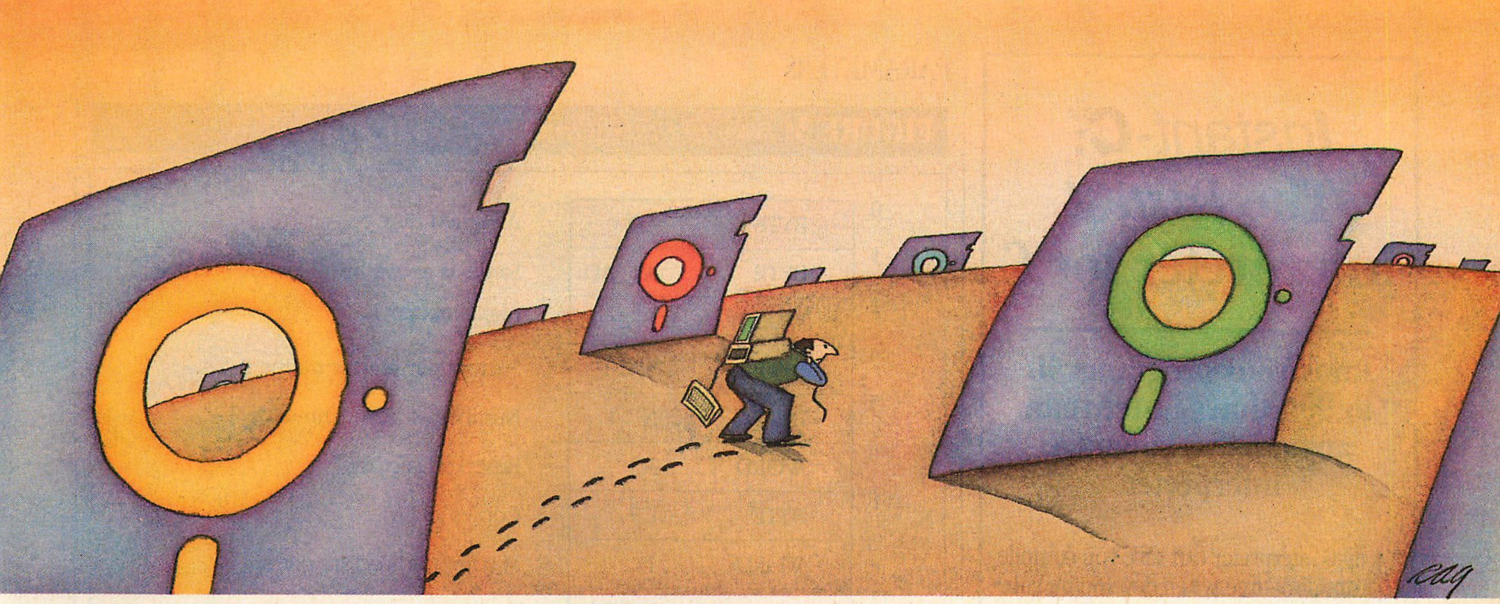
DOS function 36H provides some of the same information as functions 1BH and 1CH. Its primary function is to return the disk free space (DFS) given in number of clusters.

Two other DOS functions useful for obtaining disk information are 47H and 4EH. Function 47H returns an ASCIIZ string containing the full path name of the current working directory (CWD) for a drive. This is effective when the current directory must be changed (using function 3BH) and later restored to its original state. Function 4EH can be used to scan for a volume label containing the disk volume name (DVN), disk creation date (DCD), and disk creation time (DCT). Function 11H performs much the same job as function 4EH but requires the use of an extended file control block (FCB) and does not support path names.

The DOS boot record can be read to obtain useful disk parameters, as shown in table 1. It is the first logical sector on a disk and can be read with the DOS absolute sector read interrupt 25H. The format for the disk information in the boot record header is shown in figure 1 Unfortunately, this format was not supported on DOS versions prior to 2.0 and is only a "suggested standard" for version 2.0. For these reasons, a program should not assume the boot record contains valid disk information for systems other than IBM-supported DOS, versions 2.0 and later.

FUNCTION 32H

The undocumented DOS function 32H provides a pointer to a useful table of disk parameters. While not mentioned in the *Technical Reference*, this function has been noted in at least one piece of documentation: Appendix A of the MS-DOS 2.0 user's manual as implemented by Columbia Data Products contains a sample assembly program for reading



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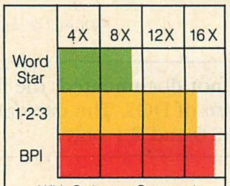

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FIGURE 3: *Format of the Function 32H Table*

Offset	Type	Name	Description
0	BYTE	AD	Assigned disk
1	BYTE	Alt_AD	Same as above but 0 for RAM disk
2	WORD	BPS	Bytes per sector
4	BYTE	SPC-1	Sectors per cluster minus 1
5	BYTE	NH-1	Number of heads minus 1
6	WORD	RS	Reserved sectors
8	BYTE	CF	Copies of FAT
9	WORD	D	Maximum directory entries
11	WORD	FUS	First usable sector
13	WORD	TCC+1	Total cluster count plus 1
15	BYTE	SPF	Sectors in FAT
16	WORD	FDS	First directory sector
18	DWORD	DDA	Device driver address
22	WORD	MD	Media descriptor
24	DWORD	*NXT	Chain to next disk table
28	WORD	Ccwd	Cluster of current working directory[a]
30		Cwd	64-byte current working directory[a]

[a] *DOS 2.0 only*

Because DOS function 32H is not documented, the format of this table could possibly change with a future release of DOS. The current working directory information is valid for DOS versions 2.0 and 2.1 only.

the FAT, using 32H to determine the FAT's size and location.

Function 32H is called by executing a DOS system request (interrupt 21H) with the following parameters:

- **On entry**
  AH = 32H
  DL = Drive number (A = 1, B = 2, ... 0 = current default drive)
- **On exit**
  DS:BX = address of table of parameters for drive
  AL = FFH if drive is invalid

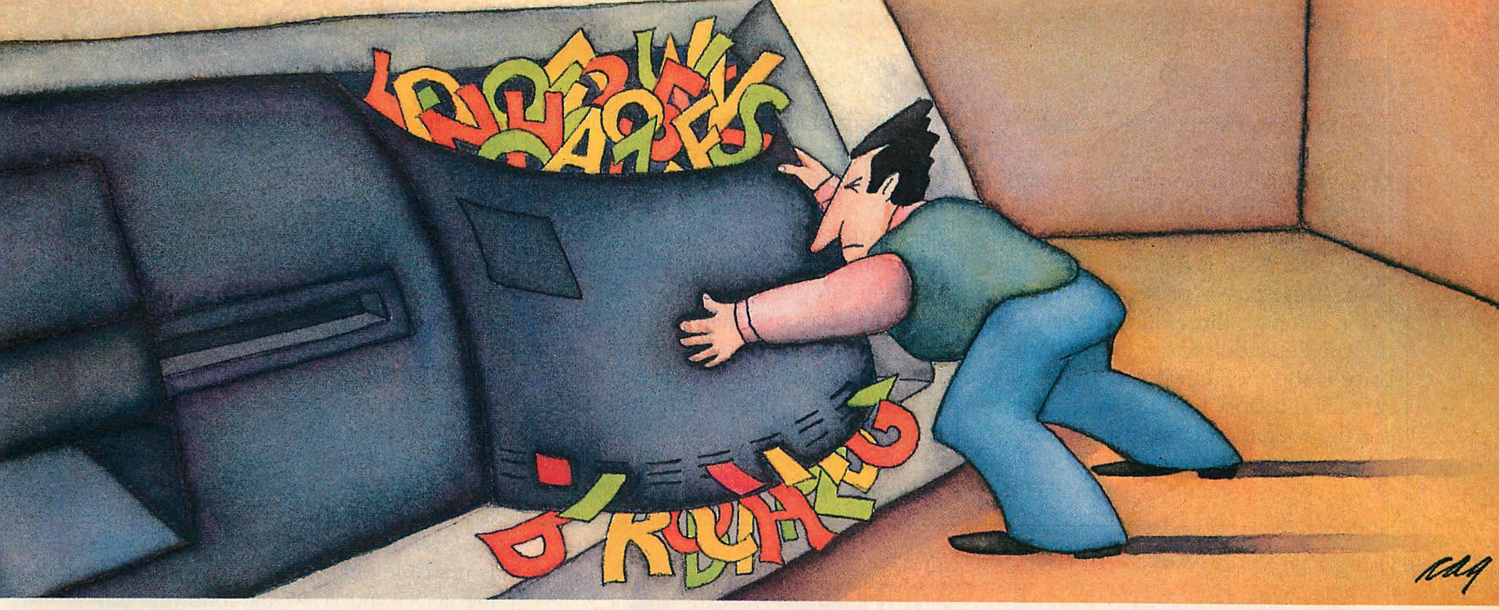
Note that assembly language programs calling this function should preserve the value of the DS register because the function changes DS to point to a DOS work area. Function 32H is supported in DOS versions 2.0 through 3.1 and may be supported in future versions. Nevertheless, good programming practice dictates checking the DOS version (via function 30) in any program that uses this function.

CHKDSK, RECOVER, and possibly other DOS utilities use function 32H to determine the size and location of the FAT and the root directory, as well as other useful information. The format of the table pointed to by DS:BX is shown in figure 3. The size and meaning of each element in this data structure were deduced from the way these parameters are used by CHKDSK and RECOVER and from observation of results on a variety of drives and disk formats.

For the most part, the data items shown in figure 3 correspond to those described earlier in this article. Some are offset by plus or minus one. Those not described earlier are the following:

AD (assigned disk). This byte indicates the original mapping between the logical drive number specified in the call to function 32H and the disk identifier (A = 0, B = 1, ...). The value differs from the drive that is specified in the 32H call if the drive identifier is reassigned with the DOS ASSIGN command prior to the execution of 32H.

Alt_AD. The Alt_AD byte appears always to have the same value as the



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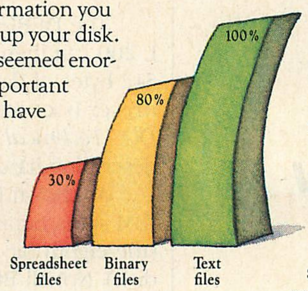

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assigned disk, except for RAM disks where it always has a value of 0.

***NXT.** This is a far pointer (offset and segment) to the next disk device table in the chain. If the low word of *NXT is FFFFH, the drive is the last in the chain.

Ccwd. This entry is present only in DOS 2.0. It can have three different values. If the current subdirectory for the target drive is the root, Ccwd is 0. If the current subdirectory for the target drive is not the root, then Ccwd usually contains the starting cluster for this directory. Ccwd is sometimes set to FFFFH. The circumstances under which this happens are not documented.

Cwd. Like Ccwd, this entry exists only in DOS 2.0. If the value of Ccwd is not FFFFH, then Cwd contains a null-terminated string representing the current working directory (CWD).

These last two fields are presented only for the sake of completeness, as they are not present in DOS 3.x. They are more easily obtained through DOS function call 47H.

Function 32H provides most of the same information as the DOS boot record but overcomes one disadvantage: the boot record cannot always be counted on to have the proper format. Although undocumented, function 32H is used by Microsoft utilities and is supported in versions 2.0 through 3.1, which covers most of the DOS installations that are in use today.

MASTER BOOT RECORD

Another source of disk information is the master boot record, which is a one-sector record maintained on hard disks that are capable of being partitioned. It is located on the first physical sector of the disk (track 0, head 0, sector 1) and is readable only via BIOS call 13H. On the PC/XT and PC/AT the following program, entered via DEBUG, can be used to read the master boot record from drive C: into address CS:200:

```
mov ax,0201  ;2=command for read
             ;1 sector
mov dl,0     ;select first disk (C:)
or  dl,80    ;8th bit indicates hard disk
xor dh,dh    ;head 0
mov cx,1     ;track 0; sector 1
mov bx,200   ;buffer address
push cs      ;
pop  es      ;read into es:bx
int  13      ;call BIOS
```

The DEBUG command **D ES:200 L 200** can then be used to display the 512 bytes of data. The layout of the master boot record is defined in the *DOS Technical Reference* in the section describing hard-disk support.

As shown in the example above, IBM starts numbering hard disks at 128 (the eighth bit is set to indicate a hard disk). Not all BIOS implementations use the eighth bit to indicate a hard disk, however. The BIOS that is used by Columbia Data Products, for example, simply reserves disks 0 through 3 for floppy-disk drives, and 4 and up for hard disks. Machines that are not PC-compatible may use totally different schemes (including different BIOS interrupt vectors) for performing absolute track and sector reads.

The final category of disk information described in table 1 is that obtainable only by searching the FAT. The computation of disk bad space (DBS) requires that the FAT be searched for the appropriate "locked-out cluster" entry (FF7H for 12-bit FATs; FFF7H for 16-bit FATs). Disk used space (DUS) can then be calculated either as:

DUS = TCC – DFS – DBS

or by counting the FAT entries that are equal to neither 0 (indicating that they are unused) nor the locked-out value.

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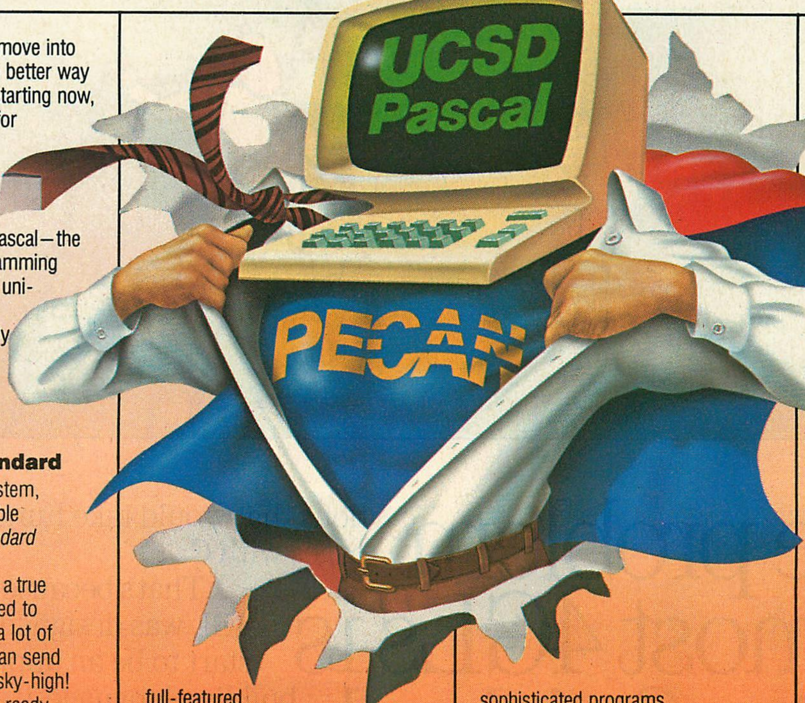

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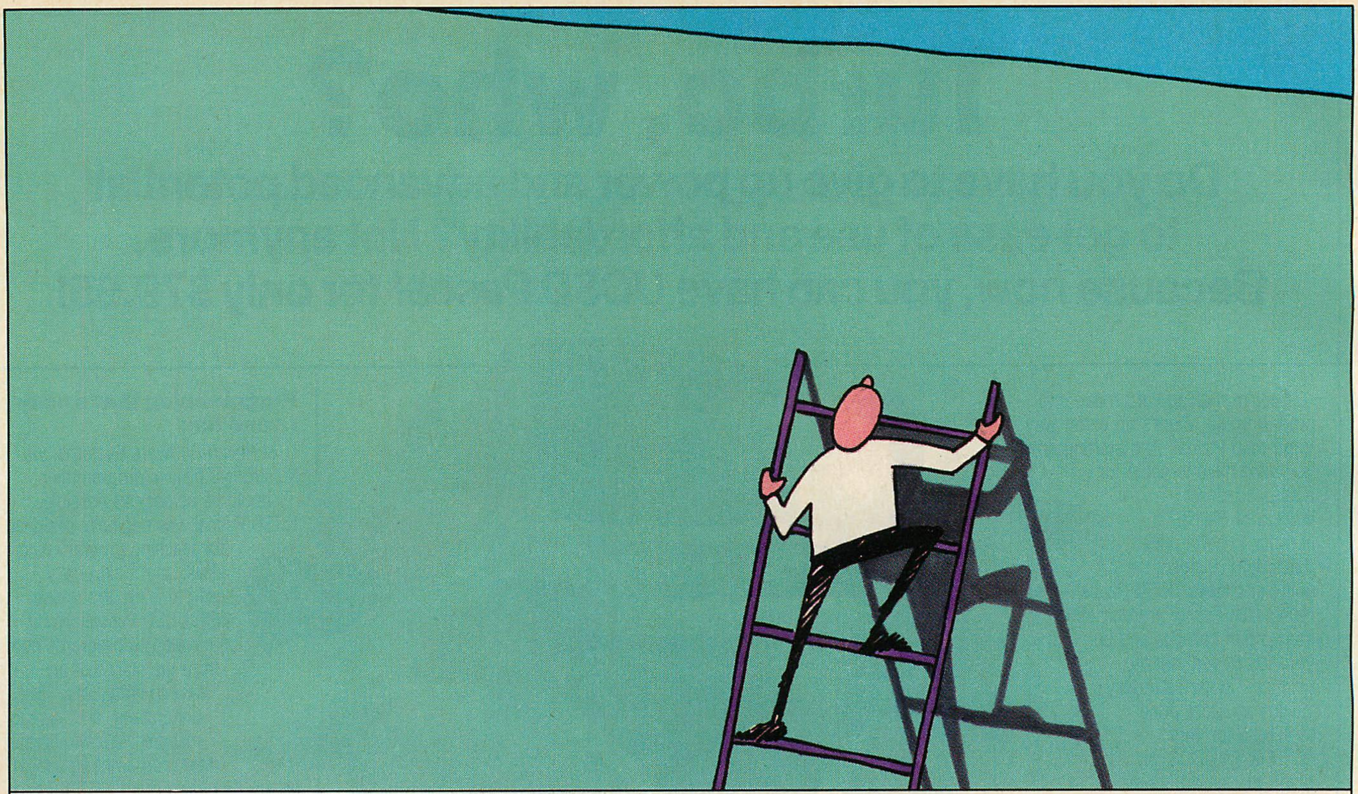

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USEFUL UTILITIES

Two system utilities that can be used to explore DOS disk parameters and directories are presented here. INFO prints out a table of information about a drive; SHOW is an enhanced directory similar to the DOS DIR command.

These programs are written in Microsoft C, version 3.0, with one exception: the absolute sector read function shown in listing 1 is written in assembly language as a subroutine designed to be called from C. It can be used to read one or more sectors from any DOS disk. The routine takes four arguments: a drive identifier (0 for A:, 1 for B:, etc.); the number of sectors to be read; the beginning logical sector; and the address of a buffer area in which to store the data.

DOS interrupt 25H is used in this routine. It behaves differently from most interrupts in that it deliberately leaves original copies of the processor flags on the stack. This is done so that return information may be passed back using the flags. However, this scheme prevents the use of Microsoft C's **int86x()** function for performing interrupt 25H. This is why assembly language was used for this portion of these programs. In this implementation the stack pointer is corrected by two INC SP instructions after the interrupt call to throw away the saved flag values.

Sector numbers are specified using a logical view of the disk. Logical sector numbers begin with 0 and are obtained by starting with physical track 0, head 0, sector 1 (physical sectors are numbered from 1 by convention) and incrementing sector numbers within a track until it is full. Once the track is full, the head number is incremented; only after all heads on the physical disk have been accessed can the track number be incremented. This logical arrangement minimizes head movement from track to track, which is the most time-consuming physical operation that the drive must undertake.

As an example, on a standard 360KB floppy disk, logical sectors 0 through 8 are on side 0 track 0, logical sectors 9 through 17 are on side 1 track 0, logical sectors 18 through 26 are on side 0 track 1, and so on.

Sectors within a track are incremented sequentially, but the physical arrangement of sectors within the track is not adjacent. This arrangement is a consequence of the interleaving of sectors, again to maximize speed of access to a given sector, taking the rotation of the disk into account. Interleaving considerations are completely invisible to driver software once an interleave factor has been set.

This description of physical to logical sector mapping may not hold for hard disks. In particular, it will not hold for bootable hard disks that maintain a partition table. Such disks store a master boot record on the first sector of the disk. This record contains the partition table as well as code to locate and pass control to a bootable partition. In addition to the master boot record, one or more partitions may be stored on the disk prior to the partition containing the specified DOS drive. The sizes of these prior partitions must be added to the offset from the first physical sector to obtain a true logical-to-physical mapping of sectors.

The INFO utility (listing 2) is invoked with the following command

```
info [d:]
```

in which **d** is an optional drive specification. If **d** is omitted, the current default drive is assumed.

A sample of the output from INFO is shown in figure 4. It includes the vol-

FIGURE 4: *Sample Output from INFO.EXE*

```
*** Information for Disk C: ***

  Volume GLENNS_DISK created  Dec  8, 1985     5:46p
  OEM name : IBM  3.1        Media descriptor (hex): f8
  Volume has 4 Surfaces, 305 Tracks with 17 Sectors/Track
  Sector size is 512 bytes.    FAT entries are 12 bits
  Cluster size is 4096 bytes (8 sectors)

Usage:                       Sectors        Bytes     Clusters
==============================================================
Hidden from DOS         |       3  |       1536  |        |
DOS Boot Area           |       1  |        512  |        |
File Allocation Table   |      16  |       8192  |        |
Root Directory          |      32  |      16384  |        |
Files & Subdirectories  |   14688  |    7520256  |   1836 |
Locked Out              |       0  |          0  |      0 |
Available               |    6000  |    3072000  |    750 |
==============================================================
TOTAL                   |   20740  |   10618880  |   2586 |

                    The disk is 70% full
```

FIGURE 5: *Sample Output from SHOW.EXE*

```
Volume in Drive C is GLENNS_DISK
Directory of C:\WORK

Filename Ext    Bytes   Actual       Last Modified        Flag    Clusters
======== === ======== ========  ===================      ====  ============
LC       BAK      170     4096  Sep 17, 1985    1:32p      a     [16f]
TEST     BAK      822     4096  Jan  8, 1986    9:29p      a     [751]
SHOWFAT  BAK     3142     4096  Oct  5, 1985    8:16p      a     [23c]
SHOWFAT3 BAK     4949     8192  Oct 16, 1985    8:29a      a     [242]-[243]
INFO     BAK     8064     8192  Feb  5, 1986   11:34a      a     [73f]
                                                                 [745]
GETID    BAK     3329     4096  Jan  5, 1986   12:18p      a     [6f5]
DOSFNS   BAK     5044     8192  Jan 23, 1986   10:01a      a     [255]
                                                                 [51e]
CTRANS   BAK      515     4096  Jan  9, 1986    9:12a      a     [877]
INFO4    BAK     8424    12288  Jan 13, 1986    1:11p      a     [729]-[72a]
                                                                 [72e]
SHOW     BAK    10022    12288  Feb  5, 1986   12:51p      a     [76f]-[771]
======== === ======== ========  ===================      ====  ============
TOTALS          44481    69632

10 Files, 7 Contiguous, 3 Noncontiguous
Files use 17 clusters @ 4096 bytes/cluster
3067904 bytes free

Files would require 49152 bytes on drive A
267264 bytes free on drive A
```

INFO tests the OEM field for validity and omits boot record information if the field contains nonprintable characters. Right: The example invocation command is SHOW *.BAK A: Noncontiguous cluster chains are indicated by cluster number lists printed on more than one line.

ume name assigned to the disk when it was formatted, the time and date the disk was formatted, the contents of the OEM field in the boot record, the media descriptor byte, the number of recording surfaces (heads) in the drive and number of tracks and sectors per track, the physical sector size in bytes, the size of FAT entries, and the cluster size. The head, track, sector, and OEM items are printed only if the disk's boot record follows the format in figure 1. The volume name, time, and date are printed only if a volume name entry is in the root directory.

In addition, a table of disk usage is printed. For each of seven types of usage the space allotted is given in bytes, sectors, and (where meaningful) clusters. The amount of space reserved is listed for the following:

- **Sectors not available**—Sectors that cannot be allocated to any file because they are too few to form a single cluster.
- **DOS boot area**—The amount of space reserved for the DOS boot record, typically one sector.
- **File allocation table**—The amount of space reserved for storage of the FAT(s) maintained on the disk.
- **Root directory**—The amount of space that is reserved for the storage of the root directory.
- **Files and subdirectories**—The amount of space used by all files and subdirectories, including *hidden* and *system* files not displayed by the DIR command and sectors used by the subdirectories themselves, a number not included in the output from DIR.
- **Bad sectors**—The amount of space locked out by DOS because of problems encountered with the media. If one sector is bad in an area of a disk, the entire cluster associated with that sector must be locked out.
- **Available**—The amount of space available for allocation to files and/or subdirectories.

For the sector and byte counts, the value shown is the sum of the entries above it in the table, and it reflects the total space in the logical image. For the cluster count, the total is also the sum of the entries above it, but it reflects only the number of clusters usable for file/subdirectory space (and locked-out clusters), not the total space on the disk. (In other words, it is not equal to the total number of sectors divided by the number of sectors per cluster.)

The last piece of information displayed by INFO is the percentage of the disk that is in use. This is calculated as the ratio of the number of clusters in files plus the number of locked-out clusters divided by the total number of clusters on the disk.

If the drive specified on the command line is mapped into another physical drive (via the DOS ASSIGN command), the first line of the output from INFO is appended with the message

(Assigned to drive x:)

where **x**: is replaced with the physical drive identifier for the target drive.

INFO uses two include files named STRUCTS.H and DOSFNS.H, which are shown in listings 3 and 4, respectively. STRUCTS.H contains most of the important data structures used by the program. DOSFNS.H contains a number of useful functions to perform DOS-related activities. Many of these use the interrupt-calling facilities provided in Microsoft C and are in that sense not transportable to other compilers. These conventions are similar to those used in other C implementations, however, and should be easy to convert.

One useful feature of Microsoft C, not currently supported by many other compilers, is the implementation of a far pointer type. A far pointer, which is a 32-bit data item consisting of a segment and offset, is particularly useful in implementing the **get_table()** function shown in listing 4. **Get_table()** returns a far pointer that is simply the DS:BX pointer obtained from DOS function 32H. This pointer can then be used as would any other pointer (using C's –> construct) in referencing elements in the table. The details of segment management are all handled by the compiler. Implementation of **get_table()** using compilers that do not have a far pointer type would be most easily accomplished by making a local copy of the table and returning a standard (near) pointer to it.

Another noteworthy timesaver used in DOSFNS.H and STRUCTS.H is C's bit field capability. This is used to define the packed bit fields in the DOS time

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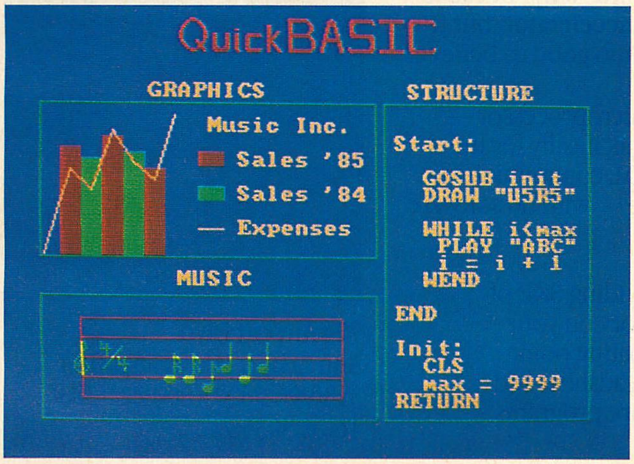

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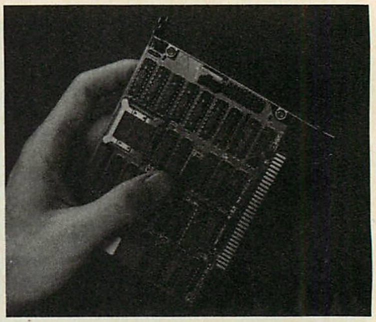

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and date structures (**ms_time** and **ms_date**). The unpacking and masking of the appropriate hours, minutes, day, month, and year elements are handled automatically by C.

The structure and function of INFO are fairly straightforward. The program first verifies that the DOS version is between 2.0 and 3.1. This is done using the global variables **_osmajor** and **_osminor** provided by the Microsoft C compiler, but could have been done as well using DOS function 30 to retrieve the major and minor version numbers.

INFO next checks for a supplied parameter and, if found, parses it for a valid drive specification. If the drive is valid, the drive's disk table is retrieved using the routine **get_table( )**, and the first sector on the drive is read into the dynamically allocated structure **bpb** using the **absread( )** routine (listing 1).

The three segments of program output are handled by the routines **print_vol( )**, **print_info( )**, and **print_tbl( )**. **Print_vol( )** uses the value of AD to determine if the drive has been reassigned. If so, the reassigned drive ID is displayed. **Print_vol( )** next searches the target disk for a valid volume label entry in the root directory. If one is found, the time and date fields for the entry are converted to ASCII strings and displayed along with the volume name. If no volume name entry is found, the message "Volume has no label" is displayed.

Print_info( ) displays general information about the drive, most of which is obtained from the disk table (**tbl**). It determines whether or not the information in the boot record (**bpb**) is usable by seeing if OEM contains only printable characters. If not, then the boot record format probably does not follow the DOS format, and thus the OEM name and track and sector information in the boot record are assumed to be invalid and are not displayed.

Print_tbl( ) displays the usage summary table and corresponding totals along with the percentage of disk use. Information on hidden sectors is included only if the boot record information is determined to be valid (again, the criterion is whether or not the OEM field contains printable ASCII characters). The sizes of the boot area, FAT, and root directory are determined from the disk table (**tbl**). Statistics on used, available, and locked-out clusters are then computed from the FAT. The routine **scan_fat( )** is used to scan the FAT for the appropriate entries.

SHOW, the second program presented here, is an enhanced directory utility that functions in a manner similar to the DOS DIR command

show [d:filename.ext [a:]]

where all or part of the file specification may be omitted. If the drive specification **d:** is not given, the current default drive is assumed. If no file name is given, *.* is assumed.

The optional second parameter can be used to specify an alternate drive for the files. If this second parameter is given, SHOW will print out the amount of space the displayed files would occupy on this alternate drive as well as the actual space available on the drive. This is useful for determining if a set of files will fit on a floppy disk.

The output of SHOW is similar to the output of DIR; however, some additional pieces of information are included. A sample of the output from SHOW is shown in figure 5.

In addition to the file size from the directory, the number of bytes allocated to the file is also displayed. In the output in figure 5, the file CTRANS.BAK is 515 bytes long, but 4,096 bytes (one cluster) are allocated to it for storage. SHOW also displays the attribute bits for the file and (unlike the DOS DIR command) lists system and hidden files. The attributes are coded as follows:

a = Archive. This bit is set if the file has been changed since it was last backed up using BACKUP (or any other utility that clears the archive bit).

h = Hidden file. Files with this bit set are not normally processed by DOS commands such as DIR and COPY.

s = System file. These files are reserved for DOS use and may have to reside in certain fixed locations on the disk.

r = Read-only file. Files with this bit set cannot be opened for write access.

Also included for each file is the chaining of clusters as computed from the FAT. This chaining is displayed as a sequence of one or more cluster numbers in hexadecimal format enclosed in square brackets. If a gap exists in the chain, the file is noncontiguous—that is, the file's allocated space is split across two or more noncontiguous locations on the disk. This can have a pronounced effect on system performance, particularly in realtime applications in which disk response time is critical. SHOW indicates file discontinuities by starting a new line for the file's output. In the example shown in figure 5, the file INFO4.BAK uses three clusters starting with the two contiguous clusters at 729H and 72AH and finishing with cluster 72EH. A gap exists between the first two clusters and the last one.

When the file listing is complete, some summary information is printed, including the total number of files; the number of contiguous files; the number of noncontiguous files; the total number of bytes used by the files; the total number of bytes allocated to the files (indicative of the true amount of space used by the files); and the number of bytes free on the disk.

If the alternate drive parameter is specified, the output also shows the amount of space that the displayed files occupy on that drive. In at least three cases, this will not correspond to the amount of space required to copy the files to the alternate drive using the DOS COPY command: (1) if any of the displayed files are hidden or system files (which are not processed by COPY), (2) if any of the displayed files already exist on the alternate drive (in which case they are overwritten by the COPY command); (3) if the files are copied to a subdirectory on the alternate drive, and the subdirectory has to be expanded to hold the new entries.

The source code for SHOW is given in listing 5. SHOW uses the same two include files as INFO, namely, STRUCTS.H and DOSFNS.H.

SHOW first verifies that the DOS version is in the range 2.0 to 3.1. Next it parses the first and second command parameters, if they exist, in DOS extended FCBs. The program then sets the appropriate bits in the FCB to request matches for hidden, archive, system, and read-only files, and passes control to the **do_entry()** routine, which proceeds to perform the main processing and display functions.

Note that because SHOW uses FCBs it is unable to process path names. Altering SHOW to support path names would involve the use of functions 4E and 4F in place of functions 11 and 12 in the **search_first()** and **search_next()** routines.

Do_entry() first gets the disk table for the target drive and (if one was specified) the alternate drive, using the **get_table()** routine. It next reads the FAT for the target drive. **Do_entry()** then looks for matching file entries in the target drive entry using the **search_first()** and **search_next()** routines. If none is found, an appropriate message is printed; otherwise the information for each matched file is output.

Output for each file consists of the file name and extension; the bytes in the file (as stored in the directory entry); the bytes actually used by the file (as computed from the FAT); the date and time the file was last modified; the flag settings; and the chaining of clusters. The printing of cluster chaining is performed by the routine **do_chain()**, which handles both 12- and 16-bit FAT entries properly.

If an alternate drive specification is given when SHOW is invoked, the program keeps track of the amount of space the files would require on this alternate drive. This total is maintained in the variable **alt_total**, which represents the number of clusters the files would require on the alternate drive. The amount of free space on the alternate drive can also be determined by using the function **getdfs()**.

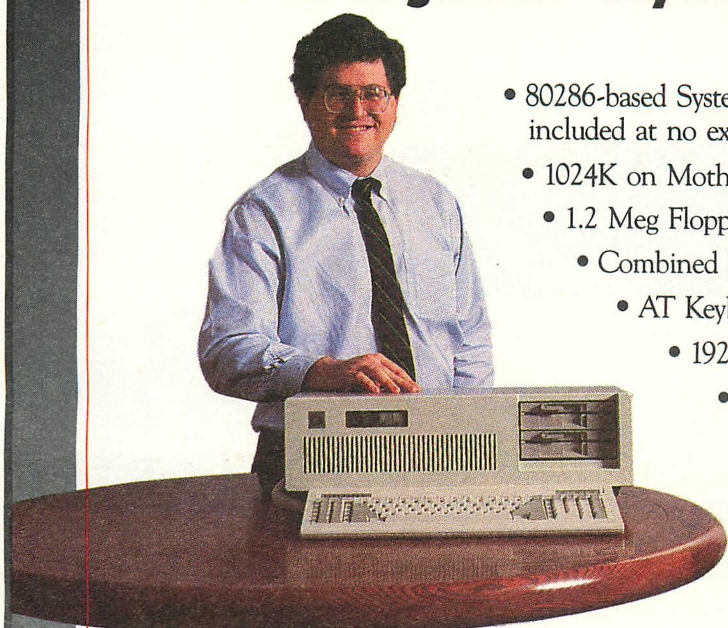
GOING FURTHER

Other useful utilities might include programs to display and edit the FAT and root directory; to recover (undelete) files; to compare the two FAT copies on a disk and replace one if it is damaged; to reorganize a disk that has become highly fragmented (that is, it contains many files that are noncontiguous).

As is the case with system utilities, each of these proposed programs has its problems and challenges. The FAT copy program may be impossible to write because DOS, in part, uses the media descriptor byte stored in the FAT to identify the disk type, and hence the size of the FAT. If the first copy of the FAT is damaged, then determining the location and size of the second copy in a generalized way may be futile. File recovery presents its own challenges because it requires piecing together information on which free clusters were formerly allocated to the deleted file. A disk reorganization program would require careful algorithm design with an eye toward efficiency and the ability to recover from power loss or interruption during recovery.

Because both DOS and mass storage devices are continually evolving, the techniques and information fields described in this article are likely to evolve as well. Function 32H may become a supported function—or it may disappear completely. Manufacturers of compatibles may finally agree on a standard format for the DOS boot record. As machines become more complex, standards grow more important, and understanding the machinery within DOS becomes essential to interpreting and using those standards.

Glenn F. Roberts, Ph.D., is a member of the technical staff of the MITRE Corporation in McLean, Virginia. His current work involves development of software for realtime processing of aviation weather data.



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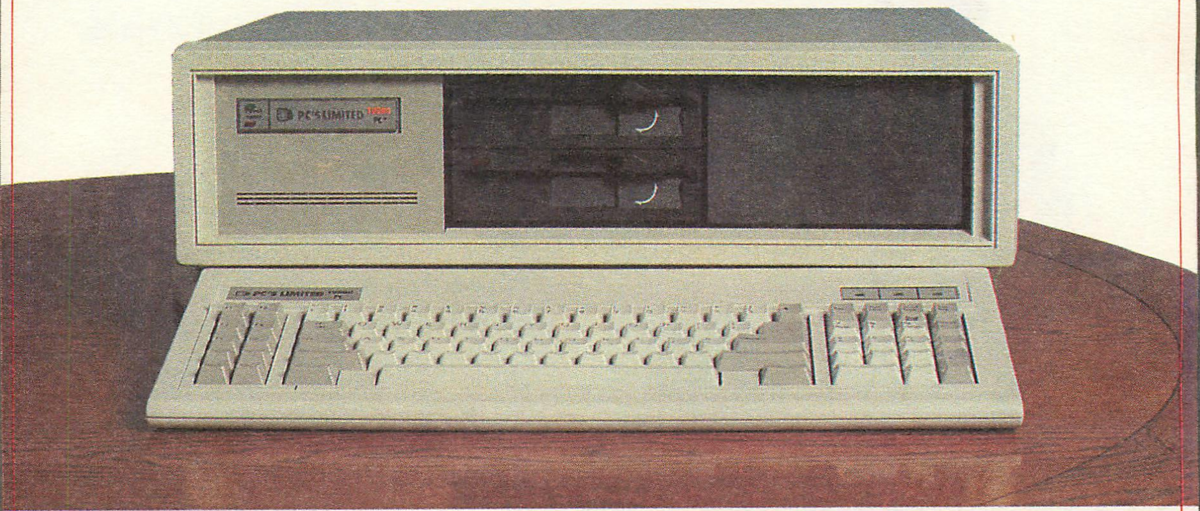

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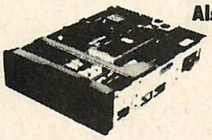

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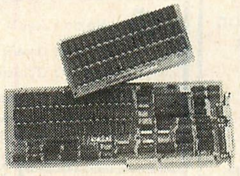

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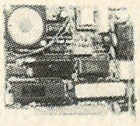

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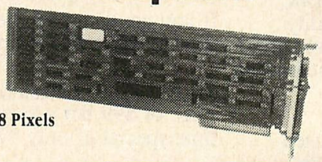

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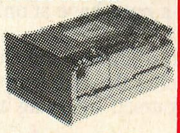

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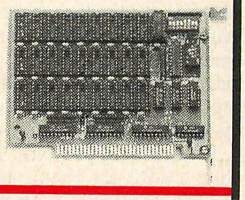

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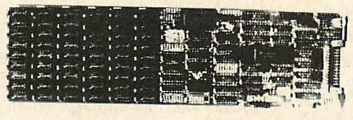

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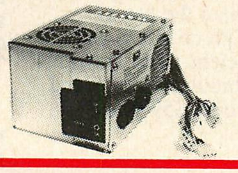

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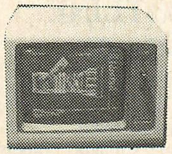

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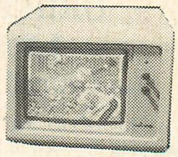

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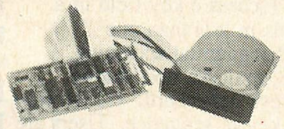

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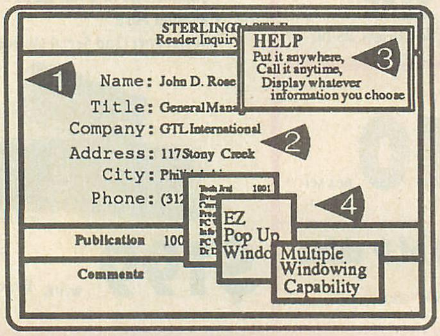

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CIRCLE NO. 183 ON READER SERVICE CARD

LISTING 1: ABSREAD.ASM

```
        PAGE        ,132

; --    absread -- absolute track and sector read
;       Version 1.1      December 30, 1985
;       Glenn F. Roberts
;       calling convention:
;               absread(drive, nsect, sector, &buffer);
;       where:
;               drive = drive no. (A=0, B=1 ... )
;               nsect = number of sectors to read
;               sector = beginning logical sector number
;               buffer = array to hold data
;       returns:
;               0       Normal return, no error
;               1       Write protect violation
;               2       Unknown unit
;               3       Drive not ready
;               4       Unknown command
;               5       CRC error
;               6       Bad drive request structure length
;               7       Seek error
;               8       Unknown media
;               9       Sector not found
;               10      Printer out of paper
;               11      Write fault
;               12      Read fault
;               13      General disk failure

_text   SEGMENT BYTE PUBLIC 'CODE'
        ASSUME  CS:_text

        PUBLIC  _absread

_absread PROC   NEAR
        PUSH    BP              ; set up stack addressing
        MOV     BP,SP
        PUSH    DI
        PUSH    SI

        MOV     AX,[BP+4]       ; AX = drive number
        MOV     CX,[BP+6]       ; CX = number of sectors
        MOV     DX,[BP+8]       ; DX = starting record
        MOV     BX,[BP+10]      ; DS:BX = buffer address

        INT     025H            ; request absolute read
        INC     SP
        INC     SP              ; fix the stack

        JC      ERROR           ; if error then return code
        XOR     AX,AX           ; else show normal return = 0
        JMP     SHORT DONE      ; and then exit

ERROR:  MOV     AH,0            ; error - zero high byte
        INC     AL              ; and increment error no.

DONE:   POP     SI              ; restore registers
        POP     DI
        POP     BP
        RET                     ; and return
_absread ENDP

_text   ENDS
        END
```

LISTING 2: INFO.C

```
#include <stdio.h>
#include <stdlib.h>
#include <ctype.h>
#include <dos.h>
#include <malloc.h>

/*  info -- This program displays useful information
**          about a DOS disk.  Output is in the form of
**          a series of general information lines followed
**          by a table showing disk space usage.  Space
**          usage is shown in sectors, bytes and clusters.
**          The program should work with all disk formats
```

```
**        including "RAM" disks.
**
**        Usage: info [d:]
**        Where d: is an optional drive specification.
**        If d: is omitted, the default drive will be
**        assumed.
**        Compiler:    Microsoft C V3.0
**        Options :    /Zp    (pack arrays)
**                     /Ze    (support "far" extension)
**
**        External modules:
**                     absread()
**        Version 1.53      February 6, 1986
**        Glenn F. Roberts
*/

#define TRUE 1
#define ENTRY_LENGTH 32
#define MIN_VERSION 200        /* DOS 2.0 */
#define MAX_VERSION 310        /* DOS 3.1 */

#include "structs.h"
#include "dosfns.h"

main(argc, argv)
int argc;
char *argv[];
{
  int drive, ver;
  struct disk_table far *get_table(), far *tbl;
  struct boot *bpb;
  static struct ext_fcb fcb = {
    0xFF,0,0,0,0,0,VOL_ENTRY,0,
    '?','?','?','?','?','?','?','?','?','?','?',
    0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
  };

  ver = _osmajor*100+_osminor;
  if ((ver < MIN_VERSION) || (ver > MAX_VERSION))
    printf("Incorrect DOS version %d\n", ver);
  else if (!((--argc > 0) ?
      (parse(*++argv, &fcb.drive_id, 1) != 255) : TRUE))
    printf("Invalid drive specification\n");
  else {
    drive = (fcb.drive_id == 0) ? current_drv() : fcb.drive_id-1;
    tbl = get_table(drive);
    bpb = (struct boot *) malloc(tbl->sector_size);
    absread(drive, 1, 0, bpb);
    print_vol(drive, tbl);
    print_info(drive, bpb, tbl);
    print_tbl(drive, bpb, tbl);
  }
}
/*  scan_fat -- Analyze FAT.  Calculate the number
**             of clusters available, in use and
**             "locked out" by DOS.
*/
scan_fat(fat, is12, fatlast, avail, locked, used)
unsigned char *fat;
int is12;
unsigned fatlast, *avail, *locked, *used;
{
  int i, cn;

  *avail = *locked = *used = 0;
  for (i=2; i<=fatlast; i++) {
    cn = fatval(is12, i, fat);
    if (cn == LOCKED_OUT(is12)) (*locked)++;
    else if (cn == AVAILABLE)   (*avail)++;
    else                        (*used)++;
  }
}
/*  print_vol --    Print volume name and creation time/
**                  date if it exists, else print that
**                  volume has no label.
*/
print_vol(drive, tbl)
int drive;
```

```
struct disk_table far *tbl;
{
  struct extended_entry dir_entry;
  static struct ext_fcb vol_fcb = {
    0xFF,0,0,0,0,0,VOL_ENTRY,0,
    '?','?','?','?','?','?','?','?','?','?','?',
    0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
  };
  int i;
  char cre_date[15], cre_time[15];

  printf("*** Information for Disk %c:", (drive + 'A'));
  if (tbl->designator != drive)
    printf(" (Assigned to drive %c:)", (tbl->designator + 'A'));
  printf(" ***\n\n  Volume ");
  setdta(&dir_entry);
  vol_fcb.drive_id = drive+1;
  if (search_first(&vol_fcb) != 255) {
    dtoa(dir_entry.body.create_date, cre_date);
    ttoa(dir_entry.body.create_time, cre_time);
    for (i=0; i<11; i++)
      putchar(dir_entry.body.filname[i]);
    printf(" created  %s  %s\n", cre_date, cre_time);
  }
  else
    printf("has no label\n");
}

/*  print_info -- Print general information.
*/
print_info(drive, bpb, tbl)
int drive;
struct boot *bpb;
struct disk_table far *tbl;
{
  int i, valid_boot;
  unsigned ncyl;

  /* If OEM name is printable then boot data are OK */
  for (i=0, valid_boot = TRUE; (i<8) && (valid_boot); i++)
    valid_boot = isprint(bpb->oem_name[i]);
  if (valid_boot) {
    ncyl = bpb->number_of_sectors/
        (bpb->sectors_per_track*bpb->number_of_heads);
    if ((bpb->number_of_sectors %
        (bpb->sectors_per_track*bpb->number_of_heads)) != 0)
      ncyl++;
    printf("  OEM name : ");
    for (i=0; i<8; i++)
      putchar(bpb->oem_name[i]);
    printf("     ");
  }
  printf("  Media descriptor (hex): %2x\n", tbl->media_type);
  if (valid_boot) {
    printf("  Volume has %d Surfaces, ", bpb->number_of_heads);
    printf("%d Tracks with ", ncyl);
    printf("%d Sectors/Track\n", bpb->sectors_per_track);
  }
  printf("  Sector size is %u bytes.", tbl->sector_size);
  printf("   FAT entries are %d bits\n",
      (tbl->last_cluster < MAX_12BIT) ? 12 : 16);
  printf("  Cluster size is %u bytes ",
      (tbl->cluster_size+1)*tbl->sector_size);
  printf("(%u sectors)\n\n", tbl->cluster_size+1);
}
/*  print_tbl -- Print table showing disk usage.
*/
print_tbl(drive, bpb, tbl)
int drive;
struct boot *bpb;
struct disk_table far *tbl;
{
  int i, nhidden, valid_boot, twelve_bit_fat;
  unsigned avail, locked, used, ntotal;
  unsigned char *fat;

  printf("Usage:                    ");
  printf("Sectors       Bytes     Clusters\n");
```

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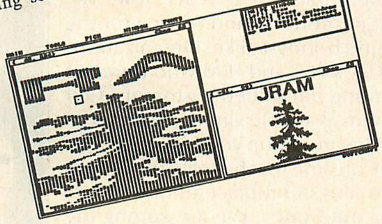

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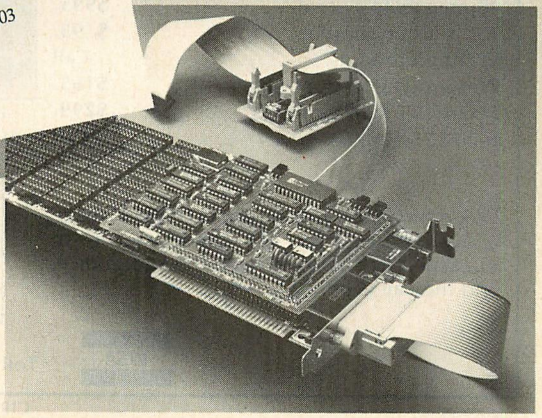

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CIRCLE NO. 194 ON READER SERVICE CARD

```
for (i=0; i<61; i++)
   putchar('=');
putchar('\n');

ntotal = tbl->fat_start + tbl->fat_copies*tbl->fat_size +
     (tbl->max_entries*ENTRY_LENGTH/tbl->sector_size) +
     (tbl->last_cluster-1) * (tbl->cluster_size+1);

/* If OEM name is printable then boot data are OK */
for (i=0, valid_boot = TRUE; (i<8) && (valid_boot); i++)
   valid_boot = isprint(bpb->oem_name[i]);

/* Print "hidden" information, if available */
if(valid_boot) {
   nhidden = bpb->number_of_sectors - ntotal;
   ntotal = bpb->number_of_sectors;
   printf("Sectors Not Available        | %7d  | %12lu  |         |\n",
        nhidden, (long) nhidden * (long) tbl->sector_size);
}
/* Print stat's on DOS boot, FAT, and root dir. */
printf("DOS Boot Area           | %7d  | %12lu  |         |\n",
     tbl->fat_start, (long) tbl->fat_start *
     (long) tbl->sector_size);
printf("File Allocation Table   | %7d  | %12lu  |         |\n",
     (tbl->fat_copies)*(tbl->fat_size),
     (long) (tbl->fat_copies)*(tbl->fat_size) *
     (long) tbl->sector_size);
printf("Root Directory          | %7d  | %12lu  |         |\n",
     (tbl->max_entries*ENTRY_LENGTH/tbl->sector_size),
     (long) (tbl->max_entries*ENTRY_LENGTH));

/* Read and analyze the FAT */
fat = (unsigned char *) malloc(tbl->fat_size*tbl->sector_size);
absread(drive, tbl->fat_size, tbl->fat_start, fat);
twelve_bit_fat = (tbl->last_cluster < MAX_12BIT);
scan_fat(fat, twelve_bit_fat, tbl->last_cluster,
     &avail, &locked, &used);

/* Print used, avail, locked out summary */
printf("Files & Subdirectories  | %7lu  | %12lu  | %6d  |\n",
     (long) used * (long) (tbl->cluster_size+1),
     (long) used * (long) (tbl->cluster_size+1) *
     (long) tbl->sector_size, used);
printf("Locked Out              | %7u  | %12lu  | %6u  |\n",
     locked*(tbl->cluster_size+1),
     (long) locked * (long) (tbl->cluster_size+1) *
     (long) tbl->sector_size, locked);
printf("Available               | %7lu  | %12lu  | %6u  |\n",
     (long) avail * (long) (tbl->cluster_size+1),
     (long) avail * (long) (tbl->cluster_size+1) *
     (long) tbl->sector_size, avail);

/* Print totals and percent disk used information */
for (i=0; i<61; i++)
   putchar('=');
putchar('\n');
printf("TOTAL                   | %7u  ", ntotal);
printf("| %12lu  | %6u  |\n\n", (long) ntotal *
     (long) tbl->sector_size, (tbl->last_cluster)-1);
printf("          The disk is %lu%% full\n",
     (used+locked)*100L/((tbl->last_cluster)-1));
}
```

LISTING 3: STRUCTS.H

```
/*  ============================================
**  structs.h -- These are various data structures
**               for use with Microsoft MS-DOS
**               function calls.
**  ============================================
*/
/*  ms_date -- packed date format used in directory */
struct ms_date {
  unsigned d : 5;
  unsigned m : 4;
  unsigned y : 7;
};
/*  ms_time -- packed time format used in directory */
```

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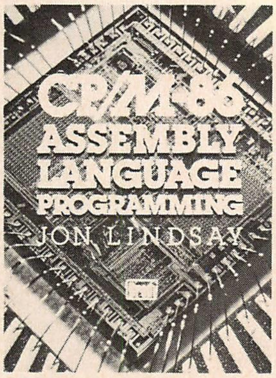

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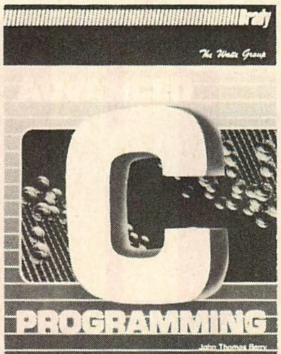

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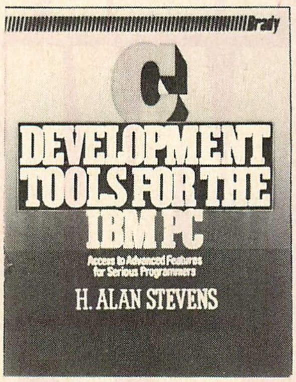

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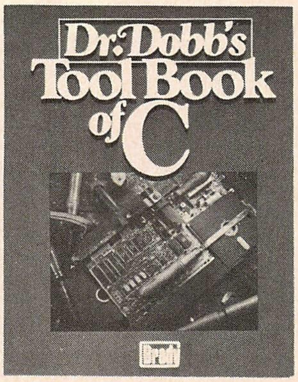

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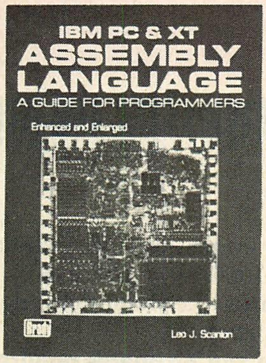

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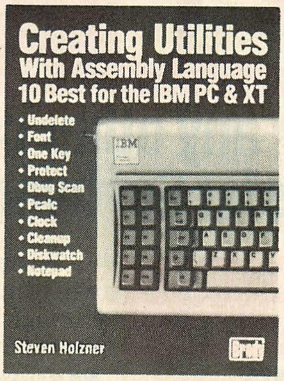

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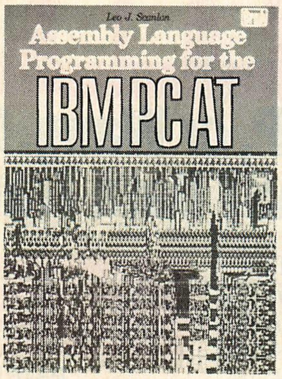

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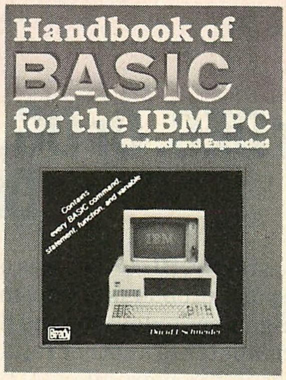

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CIRCLE NO. 161 ON READER SERVICE CARD

```
struct ms_time {
  unsigned xx : 5;
  unsigned mm : 6;
  unsigned hh : 5;
};
/*  extended_header -- header used in constructing an
**                     extended file control block.
*/
struct extended_header {
  char header;
  char zeros[5];
  char attrib;
};
/*  ext_fcb -- extended file control block */
struct ext_fcb {
  struct extended_header fcb_hdr;
  char drive_id;
  char file_name[8];
  char file_extension[3];
  unsigned curblok;
  unsigned recsize;
  long file_size;
  struct ms_date date;
  struct ms_time time;
  char reserved[8];
  char rec_in_blok;
  long rel_record;
};
/* Macros & values used in interpreting FAT entries */
#define AVAILABLE 0x0000
#define MAX_12BIT 0x0FF6
#define LOCKED_OUT(IS12) (IS12 ? 0x0FF7 : 0xFFF7)
#define LAST_CLUSTER(IS12) (IS12 ? 0xFFF : 0xFFFF)

/* Bits used in attribute field of directory entry */
#define READ_ONLY 0x01
#define HIDDEN    0x02
#define SYSTEM    0x04
#define VOL_ENTRY 0x08
#define DIRECTORY 0x10
#define ARCHIVE   0x20

/*  entry -- directory entry structure */
struct entry {
  char drive_no;
  char filname[11];
  char attributes;
  char unused[10];
  struct ms_time create_time;
  struct ms_date create_date;
  unsigned first_cluster;
  long filsize;
};
/*  extended_entry -- directory structure for use with
**                    extended file search
*/
struct extended_entry {
  struct extended_header dir_hdr;
  struct entry body;
};
/*  boot - layout of beginning of DOS boot record */
struct boot {
  unsigned char jump[3];
  unsigned char oem_name[8];         /* OEM */
  unsigned bytes_per_sector;         /* BPS */
  unsigned char sectors_per_au;      /* SPC */
  unsigned reserved_sectors;         /* RS  */
  unsigned char number_of_fats;      /* CF  */
  unsigned number_of_entries;        /* D   */
  unsigned number_of_sectors;        /* TS  */
  unsigned char media_descriptor;    /* MD  */
  unsigned fat_size;                 /* SPF */
  unsigned sectors_per_track;        /* SPT */
  unsigned number_of_heads;          /* NH  */
  unsigned hidden_sectors;           /* HS  */
};
/*  dd_header -- layout of DOS device driver header */
struct dd_header {
  struct dd_header far *link; /* chain to next header     */
  int attributes;             /* device attributes        */
  int strategy;               /* strategy routine addr    */
  int interrupt;              /* interrupt routine addr   */
  char name[8];               /* device name field        */
};

/*  disk_table -- layout of table returned by fn 32 */
struct disk_table {
  char designator;            /* PD                       */
  char alt_designator;        /* As above; 0 if RAMdisk   */
  unsigned sector_size;       /* BPS                      */
  char cluster_size;          /* SPC - 1                  */
  char heads;                 /* NH  - 1                  */
  unsigned fat_start;         /* RS                       */
  char fat_copies;            /* CF                       */
  unsigned max_entries;       /* D                        */
  unsigned first_sector;      /* FUS                      */
  unsigned last_cluster;      /* TCC + 1                  */
  unsigned char fat_size;     /* SPF                      */
  unsigned dir_start;         /* FDS                      */
  struct dd_header far *ddh;  /* DDA                      */
  unsigned media_type;        /* MD                       */
  struct disk_table far *nxt; /* chain to next disk_table */
  unsigned subdir_cluster;    /* CWD cluster (DOS 2 only) */
  char subdirectory[64];      /* CWD         (DOS 2 only) */
};
```

LISTING 4: DOSFNS.H

```
/*  ==============================================
**  dosfns.h -- Miscellaneous routine to call MS-DOS
**              system functions or perform system
**              specific tasks.
**  ==============================================
*/

/*  getdfs -- Get Disk Free Space.  Returns
**            information on disk capacity
**            and available space.
**     Input:
**         drive = target drive (A=0, B=1, ...)
**
**     Output:
**         avail = number of available clusters
**         total = total clusters on disk
**         sectsize = bytes/sector for disk
**     Returns:
**         Number of sectors per cluster
**         -1 if drive has invalid sectors/cluster
*/
getdfs(drive, avail, total, sectsize)
int drive;
unsigned *avail, *total, *sectsize;
{
  union REGS regs;

  regs.x.dx = drive+1;
  regs.x.ax = 0x3600;
  intdos(&regs, &regs);
  *avail = regs.x.bx;
  *total = regs.x.dx;
  *sectsize = regs.x.cx;
  return(regs.x.ax);
}
/*  parse -- Parse filename into FCB.  This
**           function takes a command line and
**           parses it for a file name of the form
**           d:filename.ext.
**
**           Bits in mode control parsing:
**
**           bit 0=1 : ignore leading separators
**           bit 1=1 : change drive id only if one given
**           bit 2=1 : change filename only if one given
**           bit 3=1 : change extension only if one given
**
**           returns -1 if drive invalid.
*/
parse(filename, fcb, mode)
char filename[];
struct ext_fcb *fcb;
int mode;
```

```
{
  union REGS regs;
  union SREGS segregs;

  regs.x.si = (unsigned) filename;
  segread(&segregs);
  segregs.es = segregs.ds;
  regs.x.di = (unsigned) fcb;
  regs.h.al = (unsigned char) mode;
  regs.h.ah = 0x29;
  intdosx(&regs, &regs, &segregs);
  return((int) regs.h.al);
}
/*  setdta -- Set Disk Transfer Address.
**           Sets the DOS disk transfer address
**           to be the address of buffer.
*/
setdta(buffer)
char buffer[];
{
  union REGS regs;

  regs.x.ax = 0x1A00;
  regs.x.dx = (unsigned) buffer;
  intdos(&regs, &regs);
}
/*  search_first -- Search for First Directory Entry.
**                  On entry fcb contains an extended
**                  File Control Block with file name
**                  and attribute bits set.  On exit
**                  fcb contains matched entry unless
**                  return code is 255, in which case
**                  no match was found.
*/
search_first(fcb)
struct ext_fcb *fcb;
{
  union REGS regs;

  regs.x.ax = 0x1100;
  regs.x.dx = (unsigned) fcb;
  intdos(&regs, &regs);
  return((int) regs.h.al);
}
/*  search_next -- Search for Next Directory Entry.
**                 Same as search_first except for
**                 use on subsequent calls.
*/
search_next(fcb)
struct ext_fcb *fcb;
{
  union REGS regs;
  regs.x.ax = 0x1200;
  regs.x.dx = (unsigned) fcb;
  intdos(&regs, &regs);
  return((int) regs.h.al);
}
/*  current_drv -- This function returns the drive number
**                 of the current default drive (A=0,
**                 B=1, C=2, etc.).
*/
current_drv()
{
  union REGS regs;

  regs.x.ax = 0x1900;
  intdos(&regs, &regs);
  return((int) regs.h.al);
}
/*  select_drv -- This function changes the current default
**                drive to the specified drive (A=0,
**                B=1, C=2, etc.).  Returns total number of
**                drives.
*/
select_drv(drv)
int drv;
{
  union REGS regs;

  regs.x.ax = 0x0E00;
  regs.x.dx = (unsigned) drv;
  intdos(&regs, &regs);
  return((int) regs.h.al);
}
/*  get_table -- This function returns a "far" pointer to
**               the parameters table for the specified
**               disk drive (A=0, B=1, etc.).
*/
struct disk_table far *get_table(drv)
int drv;
{
  struct disk_table far *t;

  union REGS regs;
  union SREGS segregs;

  regs.x.ax = 0x3200;
  regs.x.dx = drv+1;
  segread(&segregs);
  intdosx(&regs, &regs, &segregs);
  FP_SEG(t) = segregs.ds;
  FP_OFF(t) = regs.x.bx;
  return(t);
}
/*  dtoa -- Takes date in Microsoft packed
**          format and converts it to an ASCII
**          string as : "Mmm, dd, yr"
*/
dtoa(date, s)
struct ms_date date;
char s[];
{
  static char *mo_str[] = {
    "Jan", "Feb", "Mar", "Apr", "May", "Jun",
    "Jul", "Aug", "Sep", "Oct", "Nov", "Dec"
  };

  strcpy(s, "            ");
  if (date.m != 0)
    sprintf(s, "%s %2d, %4d",
        mo_str[date.m-1], date.d, date.y+1980);
}
/*  ttoa -- Takes time in Microsoft packed
**          format and converts it to an ASCII
**          string as : "HH:MMx", where x is
**          'a' for A.M. and 'p' for P.M.
*/
ttoa(time, s)
struct ms_time time;
char s[];
{
  int hr;
  char am_pm;

  hr = time.hh;
  strcpy(s, "       ");
  if ((hr != 0) || (time.mm != 0) || (time.xx != 0)) {
    am_pm = (hr >= 12) ? 'p' : 'a';
    hr %= 12;
    if (hr == 0)
      hr += 12;
    sprintf(s, " %2d:%02d%c", hr, time.mm, am_pm);
  }
}
/*  fatval -- This function calculates the logical
**            "chaining" of cluster numbers in a File
**            Allocation Table.  Given an entry
**            cluster number it calculates the next
**            cluster using the array fat[].
**
**            If is12 is TRUE then fat[] is assumed to
**            contain 12 bit entries, otherwise fat[]
**            is assumed to contain 16 bit entries.
*/
fatval(is12, cluster, fat)
int is12;
unsigned cluster;
unsigned char fat[];
{
  unsigned clword, cloffset;

  if (is12) {
```

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```
    /* 12 bit FAT lookup */
    cloffset = 3*cluster/2;
    clword = fat[cloffset] + (fat[cloffset + 1] << 8);
    if (cluster & 1)
      return (clword >> 4);     /* odd cluster */
    else
      return (clword & 0x0FFF); /* even cluster */
  }
  else
    /* 16 bit FAT lookup */
    return (((unsigned int *) fat)[cluster]);
}
```

LISTING 5: SHOW.C

```
#include <stdio.h>
#include <stdlib.h>
#include <ctype.h>
#include <dos.h>
#include <malloc.h>
#include <direct.h>
#include <string.h>

/*  show -- This program prints an enhanced directory
**          listing for a disk.  The output resembles that
**          from the DOS DIR command, but includes the
**          following additional information for each file:
**
**          1)  The flag settings for the file. 'a' if the
**              "archive" bit is set, 'h' if the "hidden"
**              bit is set, 's' if the "system" bit is
**              set and 'r' if the "read only" bit is set.
**
**          2)  The actual amount of space allocated for
**              storage of the file, reflecting the number
**              of clusters allocated to the file.
**
**          3)  The cluster chaining for the file.  Cluster
**              numbers are shown in hex.  Gaps are shown
**              by starting a new line.
**
**          Also displayed are totals for bytes in files,
**          total bytes allocated to files, number of files,
**          (broken down as contiguous and noncontiguous),
**          number of clusters used, and bytes of free
**          space remaining.
**
**          Usage: show [d:filename.ext [a:]]
**
**          If the drive specification d: is omitted, the
**          current default drive is assumed.  If the
**          filename or extension are omitted, '*' is
**          assumed.
**
**          If the alternate drive specification a: is given
**          the program will compute the amount of space
**          the specified files would require on this
**          alternate drive along with the actual amount of
**          space currently available on that drive.
**
**          Compiler:    Microsoft C V3.0
**          Options :    /Zp    (pack arrays)
**                       /Ze    (support "far" extension)
**
**          External modules:
**                       absread()
**
**          Version 1.35     February 6, 1986
**
**          Glenn F. Roberts
*/
#define TRUE 1
#define FALSE 0
#define MIN_VERSION 200     /* DOS 2.0 */
#define MAX_VERSION 310     /* DOS 3.1 */
#define MAX_CWD_LEN 63

#include "structs.h"
#include "dosfns.h"

main(argc, argv)
int argc;
char *argv[];
{
  int ver;
  static struct ext_fcb fcb = {
    0xFF,0,0,0,0,0,0,0,
    '?','?','?','?','?','?','?','?','?','?','?',
    0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
  };
  static struct ext_fcb alt_fcb = {
    0xFF,0,0,0,0,0,0,0,
    '?','?','?','?','?','?','?','?','?','?','?',
    0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
  };

  ver = _osmajor*100+_osminor;
  if ((ver < MIN_VERSION) || (ver > MAX_VERSION))
    printf("Incorrect DOS version %d\n", ver);
  else if (!((--argc > 0) ?
      (parse(*++argv, &fcb.drive_id, 12) != 255) : TRUE))
    printf("Invalid drive specification\n");
  else if (!((--argc > 0) ?
      (parse(*++argv, &alt_fcb.drive_id, 1) != 255) : TRUE))
    printf("Invalid alternate drive\n");
  else {
    fcb.fcb_hdr.attrib =
        HIDDEN | ARCHIVE | SYSTEM | READ_ONLY;
    do_entry(&fcb, alt_fcb.drive_id-1);
  }
}

/*  print_vname -- print volume name and
**                 current working directory.
*/
print_vname(drive)
int drive;
{
  struct extended_entry dir_entry;
  static struct ext_fcb vol_fcb = {
    0xFF,0,0,0,0,0,VOL_ENTRY,0,
    '?','?','?','?','?','?','?','?','?','?','?',
    0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
  };
  int i, drive_save;
  char current_dir[MAX_CWD_LEN+1];

  printf("\tVolume in Drive %c is ", (drive + 'A'));
  setdta(&dir_entry);
  vol_fcb.drive_id = drive+1;
  if (search_first(&vol_fcb) != 255) {
    for (i=0; i<11; i++)
      putchar(dir_entry.body.filname[i]);
    putchar('\n');
  }
  else
    printf("Unlabeled\n");
  printf("\tDirectory of ");
  drive_save = current_drv();
  select_drv(drive);
  getcwd(current_dir, MAX_CWD_LEN);
  printf("%s\n\n", current_dir);
  select_drv(drive_save);
}

/*  print_flags -- print ASCII indication of file
**                 flag settings.
*/
print_flags(attrib)
char attrib;
{
  char str[7];

  strcpy(str, "      ");
  if (attrib & ARCHIVE)   str[2] = 'a';
  if (attrib & HIDDEN)    str[3] = 'h';
  if (attrib & READ_ONLY) str[4] = 'r';
  if (attrib & SYSTEM)    str[5] = 's';
  printf("%s", str);
}

/*  do_entry -- print output for file specification
```

```
**           as parsed in fcb.
*/
do_entry(fcb, alt_drive)
struct ext_fcb *fcb;
int alt_drive;
{
  unsigned cluster, avail, total, sectsize;
  int i, drive, num_files, num_contig, total_clusters;
  int twelve_bit_fat, cluster_count, alt_clsize, alt_total;
  long size_total, actual_total;
  struct extended_entry dir_entry;
  struct disk_table far *get_table(), far *tbl, far *alt_tbl;
  unsigned char *fat, cre_date[15], cre_time[15];

  /* Get target drive information */
  drive = (fcb->drive_id == 0) ? current_drv() : fcb->drive_id-1;
  print_vname(drive);
  tbl = get_table(drive);
  twelve_bit_fat = tbl->last_cluster < MAX_12BIT;

  /* If alternate drive given, look up drive info. */
  if (alt_drive != -1) {
    alt_tbl = get_table(alt_drive);
    alt_clsize = alt_tbl->sector_size * (alt_tbl->cluster_size+1);
  }

  /* Read File Allocation Table */
  fat = (unsigned char *) malloc(tbl->fat_size*tbl->sector_size);
  absread(drive, tbl->fat_size, tbl->fat_start, fat);

  /* Search for first match of file specification */
  setdta(&dir_entry);
  if (search_first(fcb) == 255) {
    printf("No files match '%c:", 'A'+drive);
    for (i=0; i<11; i++) {
      if (fcb->file_name[i] != ' ')
        putchar(fcb->file_name[i]);
      if (i == 7)
        putchar('.');
    }
    printf("'\n");
  }
  else {
    /* Initialize and print headers */
    num_files = num_contig = total_clusters = alt_total = 0;
    size_total = 0L;
    printf("Filename Ext    Bytes   Actual      ");
    printf("Last Modified     Flag    Clusters\n");
    printf("======== === ======== ========  ===");
    printf("================  ====  ============\n");

    /* Loop over matched files */
    do {
      /* Print file name and extension */
      for (i=0; i<11; i++) {
        putchar(dir_entry.body.filname[i]);
        if (i == 7)
          putchar(' ');
      }

      /* Print size from directory and actual size */
      printf("%9ld", dir_entry.body.filsize);
      size_total += dir_entry.body.filsize;
      if (alt_drive != -1) {
        alt_total += dir_entry.body.filsize/alt_clsize;
        if (dir_entry.body.filsize % alt_clsize != 0)
          ++alt_total;
      }
      if (dir_entry.body.first_cluster != 0)
        for (cluster_count=0,
            cluster=dir_entry.body.first_cluster;
            cluster!=LAST_CLUSTER(twelve_bit_fat);
            cluster = fatval(twelve_bit_fat, cluster, fat))
          cluster_count++;
      else
        cluster_count = 0;
      total_clusters += cluster_count;
      printf("%9ld  ", (long) cluster_count *
          (long) (tbl->cluster_size+1) * (long) tbl->sector_size);
```

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The interactive intra-module and inter-module checking capabilities in EditCheck will save you many time consuming and aggravating trips between an editor and compiler.

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EditCheck's editor allows you to edit text in the current window and to copy or move text from another window to the current window. The editor supports both horizontal and vertical scrolling, and allows you to create marks and zones, move the cursor to specified objects, search and replace (case sensitive or insensitive), change case of the text, control input mode, etc.

The editor uses a file paging scheme which allows you to edit and check modules larger than your available RAM memory. Any ASCII file may be read by the editor. Files may be inserted or appended to the current window file.

The editor is both key-command driven and menu driven, or mixed usage. Key-commands are fully user reassignable.

Windows, Files, and More

The EditCheck environment is window-oriented. You may have as many windows open at the same time as you wish. Windows may overlap or be tilted, at your option. You may switch back and forth between windows, and move or copy information between them.

The windows which you open may display different files or multiple different areas of the same file. You control the location and size of all user windows, and can save the contents of a window, hide it, bury it, close it, or show it.

Windows are also extensively used by the EditCheck system to build commands, display help, show a module list, display messages, show program context while checking, etc.

A group of environment commands are available to change the coloring of windows (with a color graphics adapter and display), set the way you are notified of errors, and redefine the meaning of keys on the keyboard.

Context Sensitive Help

Help is available to you in several ways. You may use a function key to get context sensitive help particular to where you are in the system. You may select the help index, and choose a topic of interest. You may also ask the help subsystem to search for a particular word of interest within the entire system. Display of current keybindings is also available.

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```
    /* Print creation date, time and flag settings */
    dtoa(dir_entry.body.create_date, cre_date);
    ttoa(dir_entry.body.create_time, cre_time);
    printf("%s %s", cre_date, cre_time);
    print_flags(dir_entry.body.attributes);

    /* Print cluster chaining information */
    num_files++;
    if(do_chain(dir_entry.body.first_cluster, fat, twelve_bit_fat))
      num_contig++;
  } while (search_next(fcb) != 255);

  /* Print totals and summary information */
  printf("======== === ======== ========  ===");
  printf("=================  ====  =============\n");
  printf("TOTALS      ");
  printf("%9ld", size_total);
  printf("%9ld\n", (long) total_clusters *
      (long) (tbl->cluster_size+1) * (long) tbl->sector_size);
  printf("\n\t%d Files, %d Contiguous, ",
      num_files, num_contig);
  printf("%d Noncontiguous\n", (num_files-num_contig));
  printf("\tFiles use %d clusters @ %d bytes/cluster\n",
      total_clusters, (tbl->cluster_size+1) * tbl->sector_size);
  getdfs(drive, &avail, &total, &sectsize);
  printf("\t%lu bytes free\n", (long) avail *
      (long) (tbl->cluster_size+1) * (long) sectsize);

  /* Show space needed on alt. drive (if requested) */
  if (alt_drive != -1) {
    printf("\n\tFiles would require %lu bytes ",
        (long) alt_total * (long) alt_clsize);
    printf("on drive %c\n", alt_drive + 'A');
    getdfs(alt_drive, &avail, &total, &sectsize);
    printf("\t%lu bytes free on drive %c\n",
        (long) avail * (long) alt_clsize, alt_drive + 'A');
  }
}
}
```

```
/*  do_chain -- print chaining of clusters in FAT
**             (Handles both 12 bit and 16 bit
**             FAT entries.)
*/
do_chain(start, fat, is12)
unsigned start;
unsigned char *fat;
int is12;
{
  unsigned old_cluster, new_cluster;
  int i, extent_size, is_contiguous;
  is_contiguous = TRUE;
  if (start >= 2) {
    old_cluster = start;
    extent_size = 1;
    printf((is12 ? "   [%03x]":"  [%04x]"), old_cluster);
    do {
      if (extent_size == 0) {
        is_contiguous = FALSE;
        for (i=0; i<60; i++)
          putchar(' ');
        printf((is12 ? " [%03x]":"[%04x]"), old_cluster);
        extent_size++;
      }
      new_cluster = fatval(is12, old_cluster, fat);
      if (new_cluster != (old_cluster + 1)) {
        if (extent_size > 1)
          printf((is12 ? "-[%03x]":"-[%04x]"), old_cluster);
        extent_size = 0;
        putchar('\n');
      }
      else
        extent_size++;
      old_cluster = new_cluster;
    } while (old_cluster != LAST_CLUSTER(is12));
  }
  else
    putchar('\n');
  return(is_contiguous);
}
```

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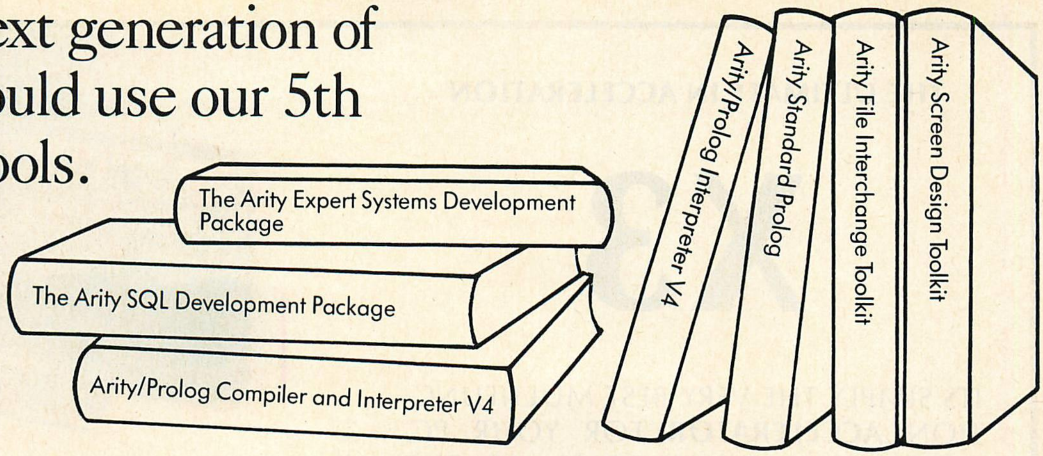

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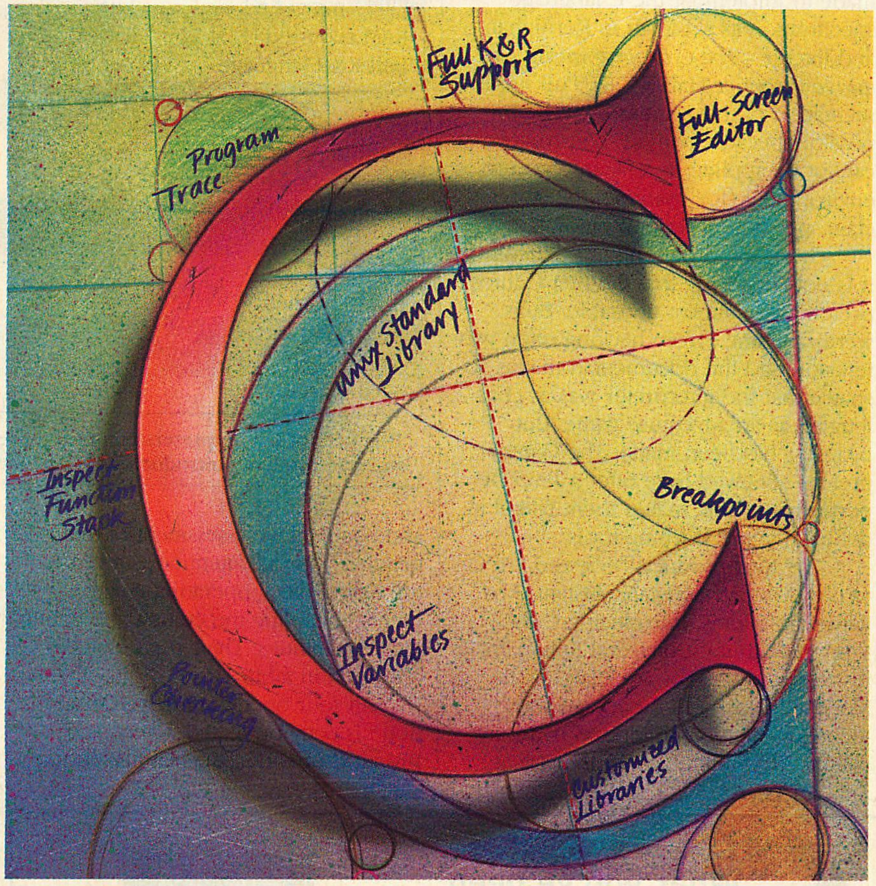
These C interpreters facilitate learning the language and writing small programs, but a full-fledged program development environment is yet to come.

The State of C Interpreters



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Learning C is a rite of passage for the serious programmer. The language is expandable enough to handle big programs and expressive enough to permit hardware-dependent and time-critical code. But this power has its price: the syntax will not catch many programming mistakes, and debugging is an arduous process.

In theory, an interpreter for this traditionally compiled language can offer the power without the price. To appreciate the difference, consider a typical programming task: a programmer must test a new function within an existing library and environment. To do so with a C compiler, he must construct a dummy main program around the function, then wait while the various compiler programs perform the transformations and write the temporary files. A C interpreter, on the other hand, will execute the function without a main program and prompt for parameters at runtime. The interpreter's transformation from source to code is performed in RAM; it is quick and transparent to the user. The programmer can single-step through source code line by line, checking values and altering variables along the way.

The designer of a C interpreter faces a formidable task. Behind the scenes, numerous header and library

files must be coordinated in a user-transparent linking process. Maximum compatibility with the many compiled C libraries on the market must be maintained. In addition, an attempt must be made to implement the C language specification as set forth in Kernighan and Ritchie's *The C Programming Language* (Prentice-Hall, 1978). Full implementation of this standard will be impossible because some C constructs cannot be applied to a PC interpreter environment (for example, the storage class specifier, described below).

Given the programming difficulties, it is not surprising that the first C interpreters were almost unusable. Bugs were rampant, error checking often was inferior, and the documentation was so sparse that the interpreter was as challenging as an adventure game. But progress has been made. The C interpreters reviewed here offer a level of performance that makes them useful as debugging and learning tools.

The four products reviewed are C-terp by Gimpel Software, Instant-C by Rational Systems, Introducing C by Computer Innovations, and Run/C Professional by Lifeboat Associates. (The Mark Williams Let's C package was judged to be a compiler and is not included.) In addition to an individual and comparative assessment of the products, special attention is given to the interpreters' operating environments, including the editing and debugging capabilities. Their basic features are listed in table 1.

TABLE 1: *C Interpreters' Features Comparison*

	C-TERP	INSTANT-C	RUN/C	INTRO. C
Version tested	2.131	1.61	1.0P	1.00H
Disk space (KB)	110	250	190	81
RAM required (KB)	256	320	320	128
Full K&R language	Yes	Yes	Yes	—
Standard library	Yes	Yes	Yes	—
PC-specific library	Yes	Yes	Yes	Yes
Sample programs	Yes	Yes	Yes	Yes
Library source code	Yes	Yes	Yes	—
Memory model	Large	Large	Large	Small
Editor	Yes	Yes	Yes	Yes
Debugger	Yes	Yes	Yes	Yes
Load libraries	Yes	Yes	Yes	—
Assembler interface	Yes	Yes	Yes	—
OBJ output	—	—	–	—
EXE output	—	Yes	–	—

This field of C interpreters includes three complete C language implementations and one product (Introducing C) designed for learning purposes only.

All four operate under DOS and none is copy protected. C-terp and Instant-C provide a special installation procedure to change screen and keyboard attributes, augmenting compatibility. C interpreters do not allow the programmer to chose memory models the way C compilers do. However, C-terp, Instant-C, and Run/C use four-byte pointers, providing access to the full 640KB memory. Introducing C has only a small model so all code and data must fit in one 64KB segment.

The disk space requirement shown in the table is the minimum amount needed to enter and run programs using the interpreter. All four can operate stand-alone—that is, without the need for additional editors, linkers, or libraries. The minimum disk space, therefore, is the size of the interpreter .EXE file itself. For most small programming jobs, a dual-floppy-drive system should be enough for any of these products. For larger applications that require additional libraries, a hard-disk system would be more convenient. The figures for RAM requirements were obtained from the vendors' documentation. All four are quite reasonable. Note that Introducing C is the only interpreter for which the RAM and diskette storage requirements are modest enough that the package can be run on a PC*jr*.

Each of the products has some language limitations (which are listed in table 2). C-terp, Instant-C, and Run/C impose only minor restrictions, similar to those programmers encounter when converting programs among different C compilers. These three interpreters support the full Kernighan and Ritchie standard for the language; however, none of the interpreters provides any of the proposed ANSI extensions. Introducing

TABLE 2: *C Language Restrictions*

C-TERP
Minor restrictions in preprocessor; #line not supported.

INSTANT-C
Comments may not be placed in the middle of an expression.
Minor restrictions in preprocessor; #line not supported.

RUN/C
No preprocessor directives other than #include or #define.
Typedefs cannot nest.
No multiline string constants.
No forward references in aggregate declarations.

INTRODUCING C
No multidimensional arrays.
No explicitly declared statics and externs.
No struct, union, dot (.), and arrow (→) operators.
No initializers.
No preprocessor directives except simple #define.
No typedef.
No casts.
No goto and labels.

Storage-class specifiers (register specifiers, for example) cannot be implemented because interpreters must allocate variables using a common symbol table and keep additional information about the variable's scope, type, and length.

C is very restricted. It supports only a subset of the C language, but C without structures and typedefs is not really C at all. These inherent limitations are enough to prevent casual programmers from running source code from a users' group or bulletin board. This subset is acceptable only for learning the language at a very basic level. (Introducing C was not designed as a professional program development tool. It is an integral part of a training system and was developed solely as a training tool.)

These interpreters also are lacking in the area of preprocessor directives: Introducing C supports none and the others support only a few. Some larger C programs use complex preprocessor operations with **#define** and macros, and they may have to be fine-tuned by hand to load under these interpreters. This is not a serious problem: any programmer who has converted from one PC C compiler to another generally learns to perform these tasks, but it is an aggravation nonetheless. Run/C also requires that **typedefs** be defined before structures that use them.

Storage-class specifiers (register specifiers, for example) cannot be used by interpreters because interpreters must allocate variables using a common symbol table and keep additional information about the variable's scope, type, and length. These interpreters simply ignore storage-class specifiers; therefore, programs that use them can be loaded and run without diagnostics. This is not a deviation from the standard, however; the Kernighan and Ritchie book says that register specifiers are a *suggestion* for the compiler, not a requirement. As reference, note that several of the C compilers reviewed in the January 1986 issue (see "The State of C," William J. Hunt, p. 82) do not support register variables.

A much more serious restriction is in the interpreters' omission of the function exit commands **setjmp()** and **longjmp()**. These functions are used in many libraries and programs, such as XLISP and Que book's ISAM, and require a detailed knowledge of the interpreter's memory management scheme. Implementing them with an external library or a hand-crafted assembly language program would be difficult.

LIBRARY SUPPORT

C-terp, Instant-C, and Run/C implement the complete standard C library. But again, Introducing C is limited It omits random-file functions such as **lseek()**, **creat()**, and **open()** and memory management functions such as **alloc()** and **free()**. These limitations suggest its use only for the novice C programmer.

All four interpreters include functions beyond those in the standard UNIX library: C-terp offers extra math and interrupt functions. Instant-C has

TABLE 3: *C Library Comparison*

	C-TERP	INSTANT-C	RUN/C	INTRO. C
UNIX STANDARD LIBRARY				
Stream files	Yes	Yes	Yes	Yes
Ato conversion	Yes	Yes	Yes	Yes
Ito conversion	Yes	Yes	Yes	Yes
Str	Yes	Yes	Yes	Yes
Random files	Yes	Yes	Yes	—
Memory management	Yes	Yes	Yes	—
Setjmp( )	—	—	—	—
PC-SPECIFIC				
Bdos ( )	Yes	Yes	Yes	—
Int86 ( )	Yes	Yes	Yes	—
Interrupt handler	—	Yes	—	—
Segread ( )	—	Yes	Yes	—
Communications	—	—	Yes	—
ADDITIONAL				
Math	—	Yes[a]	Yes	—
Trig	—	Yes[a]	Yes	—
Graphics	—	—	Yes[a]	Yes
Sound	—	—	—	Yes
LIBRARY				
Availability	Good	Good	Good	—

[a]*Provided in source form, user must read in.*

C-terp, Instant-C, and Run/C provide access to other C compiler libraries.

extra math and trig functions in source form, plus built-in interrupt call and handling functions. Introducing C includes graphics and sound functions for the beginning programmer. Run/C includes many common Lattice library functions built-in, plus extra graphics functions in source form. The library functions available with each of the interpreters are summarized in table 3.

Frequently, C users write their own extensive function libraries or purchase them from vendors. In acknowledgment of this, C-terp, Instant-C, and Run/C permit object function libraries to be loaded into the interpreter and called from an interpreted program. This capability greatly increases their usefulness in a development environment: even if the interpreter is not being used to develop full-blown programs, it can be used to write 5- to 10-line programs to check out libraries. This feature is implemented differently by each of the interpreters offering it.

C-terp has been compiled under the Lattice, Computer Innovations, and Aztec compilers and is available in one of these versions. Additional functions (.OBJ files) or libraries (.LIB files) must be compiled under the appropriate compiler. To add a function to C-terp, the source file TBLXN.C is edited and the new function's name is added to a list of externals and a large data structure. TBLXN.C is then recompiled using the same compiler as the remainder of the interpreter, and the whole interpreter is relinked. Assembler modules can be added to C-terp if they follow the interface requirements of the compiler. Although the most general of the three, this method is also the most tedious; it requires reediting and recompiling TBLXN.C each time the functions linked with it are changed. In a situation in which several add-on libraries (such as a screen handler and an access method) are used, this process could prove prohibitive.

With Run/C, loadable libraries must be compiled under Lattice's large model. The .LIB or .OBJ files then are linked with two specially provided .OBJ files, RCLMAIN and RCL2. The programmer must create another control file with extension .RCL that describes the library, including the amount of memory required and brief templates of each of the functions. Once this preparation is complete, the library (turned into a .EXE file by the linker) can be loaded directly into the Run/C interpreter with a single command.

One drawback to the Run/C system is that libraries either must be available in source form for recompilation or must have been compiled under Lattice C. This is not a major problem because most commercial libraries satisfy one of

TABLE 4: *Editing and Debugging Features*

	C-TERP	INSTANT-C	RUN/C	INTRO. C
EDITOR				
Full-screen	Yes	Yes	Yes	Yes
Paging	Yes	Yes	Yes	Yes
Insert/overlay	Yes	Yes	Yes	Yes
Search/replace	Yes	Yes	Yes	Yes
Block move/copy	Yes	Yes	Yes	Yes
Multiple buffer	—	Yes	—	—
Automatic format	—	Yes	—	—
Shell facility	Yes	Yes	Yes	—
Goto last error	Yes	—	Yes	Yes
DEBUGGER				
Trace	Yes	Yes	Yes	Yes
Breakpoint	Yes	Yes	Yes	—
Single step	Yes	Yes	Yes	—
Side step[a]	Yes	Yes	Yes	—
Pointer check	Yes	—	Yes	—
Display variables	Yes	Yes	Yes	Yes
Display memory	—	Yes	—	—
Alter variables	Yes	Yes	Yes	—
PROGRAM PROFILER	—	—	Yes	—
SIDEKICK COMPATIBLE	Yes	Yes	Yes	Yes

[a]*Side step means to single step through source but execute function calls at full speed.*

This group of interpreters brings BASIC's debugging power to the C language.

these criteria. The advantage to using this system is that when a function changes, only the individual library that contains it need be relinked, not the entire interpreter.

Finally, the Instant-C interpreter permits .LIB or .OBJ files to be loaded directly with a preprocessor directive provided they are compiled under the Lattice small memory model (limiting each loaded module to 64KB) or, if in assembly language, they were written using the Lattice compiler's calling conventions. While it is the easiest to use, the Instant-C method may present a problem if the desired functions are not available in the small model.

EDITING OPTIONS

All four C interpreters provide a user interface that has a full-screen editor. Their individual features, and those of the debuggers, are summarized in table 4. The Introducing C editor is the simplest of the four (many Introducing C users, having moved up from BASIC, may never have used a full-screen editor). It does exhibit an annoying flicker during screen updates, but its commands include the ability to copy and move lines, in addition to most basic editing functions. Many of this interpreter's commands are activated by the first letter of their name, such as *C* to change text or *W* to write a file.

The Instant-C editor is the most sophisticated. Unlike the others, it is object oriented: instead of working on an entire source file, editing is done on individual functions and global variables. But this feature can be annoying because the header portion of a source file, where global variables are defined, cannot be viewed in its entirety. One of its better features is automatic formatting and block comment supplied when the function is entered; this encourages the programmer to use a readable coding style. The Instant-C editor is also the only one to support multiple editing buffers, and it permits cutting and pasting text between them. The keyboard may be customized using a special definition program. Finally, the package includes a stand-alone version of the editor, presumably for editing non-C files outside of the Instant-C environment.

Instant-C is the *only* interpreter that permits multiple source files in memory at the same time. This is an important feature to writers of large programs. The best a programmer can do without multifile editing is assemble a user library and test one file at a time. However the terse Instant-C documentation discusses this feature only briefly.

The Run/C interpreter has been overhauled and a new, full-screen editor added. This editor uses WordStar-like control-key commands to perform

many of its functions, such as moving and deleting blocks. Users familiar with the Borland Turbo Pascal or SideKick editors will find no surprises here. One unique feature of Run/C is an ability to specify an external DOS editor and call it from the interpreter with a single command, provided enough RAM is available to permit both the editor and interpreter to be resident. The current source file is automatically saved in the current directory as PROGRAM.C, then reloaded back into the interpreter when the editor exits. This feature permits a programmer to use his own editor in at least a partially integrated manner with the rest of the Run/C environment.

C-terp's editor features Alt-key combinations that are named according to some mnemonic merit (for example Alt-H for help and Alt-G for a global search). It offers many standard features, such as block move and copy, but like the other editors, it is neither obtrusive, nor particularly powerful.

Deciding among four unique editing styles and user interfaces can leave a programmer wishing for a PC text-editing standard. Moreover, none of these editors is as powerful as some DOS-based programming editors, such as Phoenix PMATE, a fact that is sure to dissatisfy experienced C programmers.

GREAT DEBUGGING

In contrast, all of these products offer convenient debugging facilities, because the source and symbols of the programs are immediately available and no special compilation is needed to include this information in a .EXE file. All four can trace a program's execution, permitting optional viewing of the function stack and expression results. Beyond simply tracing execution, C-terp, Instant-C, and Run/C, can stop a program during execution, examine its variables, change them, and resume. The programmer implements this capability through special functions inserted into the program at desired breakpoints. Once stopped, the interpreters permit inspection and modification of variables, as well as single stepping.

The improper use of pointers is a common bug in C programs. A program that contains such a bug can overwrite memory, causing disastrous results. Normally, C compilers do not perform pointer checking, in order to make the object code generated as small and fast as possible. However, two of these interpreters—Run/C and C-terp—provide this capability. In both, an improperly used pointer in a running program causes an error display and halts program execution. Run/C pointer checking can be switched on and off with the appropriately named SET TRUST command. C-terp pointer checking cannot be disabled completely. Minimal checking is retained even when full checking is disabled: pointers are checked only for zero segment. This protects some vital areas of memory, while speeding up execution. C-terp also permits selective checking of pointer arguments in external functions using flags in tables contained in TBLXN.C. Pointer checking is a good feature to have, especially when converting a program from small to large compiler models.

Run/C includes another helpful tool, a program profiler, which profiles a single function or range of lines; it can be activated as a command or within a program. The profiler counts the number of times each line is executed—an indication of the program's performance. While not a debugging feature per se, this is a convenient capability in an interpreted environment.

All four products are compatible with SideKick, a handy utility during

programming. More importantly, this indicates that all four play by most of the rules for IBM compatibility—no non-standard keyboard or screen handling that can make their use with other programs or with LANs difficult.

IN WRITING

The products' documentation ranges from sparse to quite complete, as the summary in table 5 indicates. Documentation for a C interpreter should reflect its dual purpose as a productivity tool for advanced programmers and as a learning tool. However, only Introducing C provides basic material for new C programmers, and in this area, it is excellent. Its manual is organized into modules ideal for self study; a week or two with this package provides a very worthwhile hands-on experience with most fundamental C concepts. The Introducing C manual lacks technical details about the interpreter, but this flaw is not that serious considering its intended audience: novice programmers.

The other three products do not provide material for beginning programmers. They simply list the interpreter's features and functions. Of the three, the Run/C documentation is the best written and contains the most information. Instant-C's manual is the next best; but it is hurt by offering only minimal technical information, especially in the critical area of loading libraries and object modules. In particular, it contains little about the unique Instant-C ability to generate a stand-alone .EXE program out of source files. C-terp has the worst documentation, a sparse 104 pages with no index. A beginner will need a good C programming primer and *The C Programming Language* with any of the products except Introducing C.

Source code is an excellent source of technical information, and all of the interpreters supplied some. Run/C's is the most extensive, with a complete graphics library and well-documented sample programs for nearly every function in the interpreter's library. Instant-C supplies source code for parts of its library, including the trig and math functions. C-terp offers a few sample programs in addition to the code for TBLXN.C. Introducing C has a "built-in" library; its header can be customized and functions can be added to it by inserting source code into the library source file. Several sample programs also are included.

All four interpreters underwent substantial revision and debugging during the time this article was being written. Therefore, update information is important. Instant-C, in keeping with the experimental nature of this kind of product, offers free upgrades to registered users. Users are charged for updates to C-terp and Introducing C. The Run/C purchaser will receive a free update if he is the first to report a bug.

TABLE 5: *Documentation Comparison*

	C-TERP	INSTANT-C	RUN/C	INTRO. C
Installation	Good	Fair	Good	Good
Set-up	Good	Fair	Good	Good
Tutorial	—	—	—	Good
Editor	Poor	Fair	Good	Good
Error messages	Fair	Good	Good	Good
K&R differences	Poor	Poor	Good	Good
Library reference	Fair	Fair	Good	Good
Linking externals	Poor	Poor	Good	—
Assembler information	Poor	Poor	Good	—
Technical details	Good	—	Good	—
Source code	Fair	Fair	Good	Fair
Updates	Fair	Good	Good	—
Index	—	Fair	Good	Good
Overall rating	Fair	Fair	Good	Good

Documentation often takes a back seat when software is still being perfected. The manuals for C-terp and Instant-C did not match the quality of the programs.

TABLE 6: *C Performance Benchmarks*

	LATTICE C	C-TERP	INSTANT-C	RUN/C	INTRO. C
SIEVE.C	0.2	49.0	0.4	228.0	394.0
FILECOPY.C	4.0	4.0	3.0	4.0	N/A
PENTATH.C					
Floats	5.0	21.0	4.3	90.0	163.0
Functions	0.3	45.0	0.6	131.0	275.0
Strings	0.3	81.0	0.7	246.0	366.0
Chars	0.2	11.0	0.1	50.0	96.0
Files	3.0	60.0	9.3	189.0	996.0
Makefile	2.2	42.0	5.1	142.0	593.0
INDEX	0.6	55.5	1.0	186.7	455.4

All times in seconds.

The Lattice C compiler has been included for comparison. Index means the average ratio of a program's execution time versus Instant-C's execution time.

BETTER THAN COMPILING

To a point, all of these interpreters are convenient to use. Trade-offs have been made in favor of power (Instant/C) or ease-of-use (Introducing C), but this is dictated by their intended audiences. Moreover, using any interpreter is preferable to editing, compiling, and linking programs with a C compiler.

The performance benchmarks in table 6 highlight the major differences among these products. Three programs from the *PC Tech Journal* benchmark suite were run on each interpreter. They were written by William J. Hunt for his article "C and the PC" (November/December 1983, p. 110). The source code for these benchmarks is available for downloading on PCTECHline. Each test is described below.

SIEVE.C is the Sieve of Eratosthenes, which finds prime numbers. It tests an interpreter's looping, integer math, and array subscripting speed. For these evaluations, the array size was reduced from 8,192 elements to 1,024 so that the tests would finish in a reasonable amount of time. In this test, Run/C and Introducing C were quite slow.

FILECOPY.C copies one file to another, first filling a 16KB array with data from the input file, then writing it all to the output file. This benchmark tests an interpreter's speed in a systems program setting, using command line arguments, the **creat()** and **open()** low-level file calls, and looping. This test could not be run on Introducing C

because **creat()** and **open()** are not included in its library.

PENTATH.C is a suite of six tests: floating-point math, dummy function calls (important in an interpreter because a great deal more overhead is involved in keeping track of the variables passed), string copying, character processing, file copying, and writing a large file. For these interpreters, the loop limits had to be reduced by a factor of 10, and sometimes 20.

The benchmark programs were run on an Alpha Micro Workstation (a PC/XT look-alike) with 512KB of RAM, a 10MB hard disk, and an STB Chauffeur video card, and running DOS 2.1. No CONFIG.SYS file was present, and the system was rebooted after each benchmark to avoid interference by DOS disk caching. The same files were used for all four interpreters and they were kept in the same location on the hard disk to eliminate the effects of directory searches and space fragmentation.

Because compile times are virtually instantaneous for all four interpreters and storage use was difficult to determine (the interpreters use preallocated symbol tables, for example, so variable storage requirements remain constant when different size programs are loaded), only execution times are presented here. Unfortunately, these times could not be obtained using the PC system clock because Introducing C has no DOS interrupt capability. Instead, each benchmark was timed with a stopwatch; but this should not be considered a liability in making comparisons because of the sizable differences in the benchmark results. Note that the tests also were compiled using the small model of Lattice C 2.15 to offer a frame of reference against an optimizing compiler.

Clearly, Instant/C is the performance champion. Furthermore, in every test but one (the file-copying portion of PENTATH.C) its times compare well with the Lattice compiler. This interpreter was tested last, using the scaled-down versions of the tests *required* by the other three products. Time after time, the Instant/C prompt was staring back just barely after pressing Enter. Most of the elapsed times for Instant/C (and the Lattice compiler .EXE files), therefore, were obtained by running the tests 10 or 20 times and dividing by the number of iterations. Rational Systems says that Instant/C uses a proprietary form of incremental compilation. This process retains enough information about the original source program so that no separate source file is required; when a function or global variable is edited with Instant/C, it is recreated from the object code.

The second best performer, C-terp, is quite a technical accomplishment. It turned in rather respectable times, considering its small size. The manual's design notes say that this interpreter is written mostly in C with critical portions in assembly language for speed. An intermediate, tokenized language that speeds up execution is produced from source code (like a BASIC interpreter). It did, however, display a minor lag in converting to tokens and converting back to source code.

Run/C and Introducing/C are slow. In fact, both are much slower than interpreted BASIC. (A BASIC SIEVE benchmark on the same machine took 26.0 seconds with BASICA and 0.2 seconds with the BASCOM 1.0 compiler. The source code of the BASIC benchmark, SIEVE.BAS, is available on PCTECHline.) These C products are slower than BASIC because both interpret the program's source code with little intermediate tokenizing. While this makes switching between editing and

running programs go quickly, a penalty is paid in execution time. This lesser performance may be acceptable for learning, debugging, and library check-out because the amount of code executed tends to be small. However, it becomes prohibitive to use these interpreters for large programs.

FOUR Cs

The current assemblage of C interpreters is discussed below. Each seems oriented to a particular segment of the C programming audience. All of the products require an IBM PC or compatible, one disk drive, DOS 2.0 or later, and either a color or monochrome display. Run/C and Instant/C require 320KB of memory; C-terp requires 256KB, and Introducing C requires 128KB.

Run/C Professional. Written by Age of Reason and published by Lifeboat Associates, Run/C is available in two versions: the professional version tested here and a smaller version, called Run/C: The C interpreter, which does not include loadable library support. This smaller version is intended for beginning C programmers.

Run/C comes packaged in an IBM-style binder and slipcase. The documentation is clear and thorough, and includes a good index, careful library descriptions, and many examples. The manual goes beyond a functional description of Run/C to explain how the interpreter was designed and written.

In action, Run/C resembles interpreted BASIC: a row of function key labels appears at the bottom of the screen in reverse video, and typing commands or statements is answered by "Ok." F2 is used to run the program, starting with **main()**, and F6 edits the source of the last error received. Functions not activated with function keys are performed using BASIC-style commands, such as LOAD and LIST. When a breakpoint is reached in a program, it enters a mini menu that permits examination and changing of variables, interactive execution of statements, or statement tracing. Programmers with even a casual familiarity with BASIC will find Run/C easy to use.

Despite its poor showing in the time trials, Run/C is a solid product that performs many tasks well. It includes most of the functions from the Lattice compiler's library, and supports the full Kernighan and Ritchie standard. This entire package displayed a polish in important areas, such as its manual, user interface, and messages, that is missing in the others. It was the only package to include sample source files for every function in its library. Run/C is suitable for programmers who will be using the interpreter to debug programs and to check libraries, but its slow performance does not recommend it for writing large programs.

C-terp. This interpreter from Gimpel Software performed well through most of this evaluation. In addition, it offers some unique features.

C-terp uses a menu-based user interface that resembles pfs:write and pfs:file by Software Publishing. The editor, debugger, and file handling are invoked from this main menu. The menus work smoothly and should be comfortable even to the experienced programmer accustomed to command-oriented execution. When the debugger is in use, the editor is available in browse (read-only) mode in a separate window, so the source code of the program being interpreted is visible for reference. A smaller menu similar to Run/C's, although less functional, also is displayed; it permits the programmer to execute statements, display variables, single step execution, etc.

The benchmarks show C-terp to be a fairly fast C interpreter. It supports the full Kernighan and Ritchie C definition, in addition to a good-sized library. Its primary problems are terse documentation (a poor comment for a $300 software product, however technical the audience) and a potentially clumsy loadable library scheme. The manual, packaged in a fabric binder and slipcase, comes with four diskettes. This interpreter might be a good choice for the veteran programmer or for the hobbyist who is able to work with a minimum of product documentation.

Introducing C. Computer Innovations produces this C interpreter in addition to a C compiler, Optimizing C86, which was reviewed in the January 1986 issue. Based on its documentation and the functions offered, Introducing C clearly is intended for beginning C programmers, not as a development environment. In earlier versions, this product was copy protected; fortunately, this was removed in the latest version.

This interpreter is a good starting point for the new programmer who wants to learn the C language and graduate at some point to a compiler. Although it lacks many important C features, such as structures, this product implements enough of the language to *introduce* C to the beginner. The notably excellent manual goes a long way itself in teaching the language, providing many examples toward that end. Moreover, even with its slow execution times, Introducing C includes adequate graphics and sound functions to keep a new programmer at least interested.

In spite of all this, the novice user probably will need to leave the nest someday. It does a good job of error detection, but Introducing C lacks the speed and features necessary to the experienced programmer; its debugging support, in particular, is insufficient to handle large or complex programs. A user would need to carry programs written in Introducing C over to a C compiler and go from there.

In short, this product lives up to its name in offering the programmer a smooth beginning into the C language. (Even the packaging is uncomplicated: a Turbo-style paperback manual and a single diskette.) In this area, none of the other three products can compare.

Instant-C. This interpreter from Rational Systems is intended as a complete C development tool for beginning and experienced programmers alike. But the product's environment effectively limits the audience to seasoned C veterans who probably already feel comfortable with their C compilers and debuggers. The Instant-C user interface, when not in the full-screen editor, resembles a UNIX terminal session, with numerous cryptic commands to control every detail of the session. Prompting and help information is minimal. So, despite the documentation's claim that Instant-C is ideal for new users, only serious programmers need apply.

This acknowledged, Instant-C is a powerful, complex C interpreter, offering the experienced programmer many valuable facilities. Its strong points are a full support of the language and standard library and an unbelievably fine performance. What is surprising is that such an advanced product should want for a better manual. The documentation included, in an IBM-sized binder with two disks, is painfully brief. In spite of this, Instant-C can help C programmers improve their productivity.

C INTO THE FUTURE

Before purchasing a C interpreter, the programmer must have a good understanding of what such a program can do. It can provide an amicable environment for learning C, along with easy editing and excellent debugging. It cannot (as yet) provide the speed, flexibility, or reliability of a compiler. The pro-

grammer can neither chose a memory model, nor place a variable in a register for greater speed. Also, these interpreters are not fast enough for time-critical projects such as interrupt routines that manage hardware. Finally, C interpreters are still under development; this is evident in their documentation, which often takes a back seat when software is being perfected.

Introducing C is the least likely to interest the program developer. It fulfills its educational goal admirably, but its language implementation is limited. C-terp is a fast implementation of the full language, but its documentation leaves the user guessing. The Instant-C documentation also is sparse, but this product holds the promise of becoming a powerful workbench for C programming, reminiscent of the environments available for languages such as Smalltalk and LISP. It is designed for large program development, and its speedy performance makes it a good prospect.

Finally, in spite of its rather slow execution, Run/C outclasses the other products in several important categories, most notably its documentation, user interface, and add-on library support. For the present, it is the overall best choice in a C interpreter.

C-terp 2.131: $300
Gimpel Software
3207 Hogarth Lane
Collegeville, PA 19426
215/584-4261
CIRCLE 341 ON READER SERVICE CARD

Instant-C 1.61: $495
Rational Systems, Inc.
P. O. Box 480
Natick, MA 01760
617/653-6194
CIRCLE 342 ON READER SERVICE CARD

Introducing C 1.0H: $125
Computer Innovations
980 Shrewsbury Avenue
Tinton Falls, NJ 07724
201/542-5920
CIRCLE 343 ON READER SERVICE CARD

Run/C Professional 1.0P: $250
Lifeboat Associates
1651 Third Avenue
New York, NY 10128
212/860-0300
CIRCLE 344 ON READER SERVICE CARD

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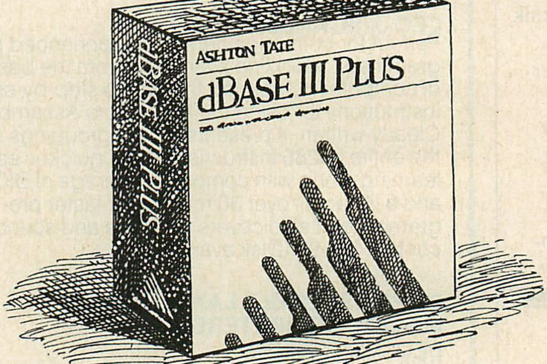
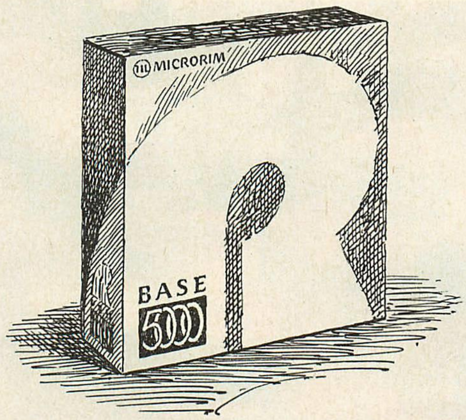
YOU CAN STRUGGLE A LOT READ A LOT WORRY A LOT AND PAY A LOT.



OR NOT.



It's the difference between spending time studying your software, and spending time developing your applications. At Microrim, we don't think you should have to struggle with an application generator that limits your choices to one of everything. (Like just one menu, and access to only one table.) Or be forced to read through dozens of pages of technical instructions just to figure out how the password system protects your files.

APPLICATION DEVELOPMENT

	R:base 5000	dBASE III® PLUS
Application Generator		
▪ Multi-table Access	Yes	No
▪ Nested Menus	Yes	No
▪ Custom Reports	Yes	No
▪ Reviseable Applications	Yes	No
Password Security		
▪ Pages of Documentation	1½	36
▪ Usable by Nontechnical User	Yes	No
Automatic Protection Against "Deadly Embrace"	Yes	No
List Price		
▪ Single-User	$ 700	$ 695
▪ Multi-User		
5 Users	$1,500	$2,385
10 Users	$1,500	$3,680
20 Users	$1,500	$7,360

We also don't think you should have to worry about the possibility of locking up the system when two users go after the same record (a "deadly embrace"). Or have to pay extra each time you want to add a user to your database network.

That's why we built R:base™ 5000 just the way it is. Powerful, straightforward, and *complete*. (See the chart.) Which is probably why Datapro rates it as the best DBMS on the market, bar none.

But judge for yourself. For $9.95 (plus shipping), we'll send you our R:base 5000 single-user demo. Or our multi-user demo for only $50 (shipping included). Just call 1-800-547-4000 and ask for Dept. 936. From Oregon, or outside the U.S., call 1-503-684-3000, Dept. 936.

After all, when it comes to developing applications, you can either put yourself through a lot.

Or not.

R:BASE 5000
FROM MICRORIM

DATA MANAGERS AS DEVELOPMENT TOOLS

A Data Manager:

The Evolving Standard

COMPUTER GRAPHIC • DOV JACOBSON

Underlying all its new features is the original dBASE, but dBASE III PLUS has evolved into an efficient product.

DAVE BROWNING

To the venerable dBASE product line, Ashton-Tate's latest addition brings multiuser database processing for local area networks, additional features for developers, and a new interface for end users. dBASE III PLUS is intended both for end users and for developers working independently or within corporations to solve database applications needs.

Power database end users who understand the dBASE file, index, and data relationship concepts and structures will find most of their wish-list items in dBASE III PLUS. Independent applications developers will miss a true source code compiler, a more powerful report generator, and easier programming of data entry screens. The corporate technical support staff will find dBASE III PLUS suitable for developing applications for corporate users who have some training or experience with any dBASE version.

dBASE III PLUS is not revolutionary. It is evolutionary by design, based on Ashton-Tate's view of the needs of the marketplace, and is intended to provide a substantial quantity of new features in the basic mold of the existing product. As an upgrade to the basic product, dBASE III PLUS runs most existing dBASE III applications, extends the development language, adds more power to the interactive user interface, improves performance, and provides rewritten documentation. As an evolutionary product adding new features, it adds fresh capabilities such as networking, password protection, data encryption, applications generation, source code pseudo-compilation, linkage to compiled subroutines, and runtime facilities.

As with the existing dBASE III program, dBASE III PLUS organizes data in files and provides commands for linking files into a database. The command language includes the features of a general purpose structured programming language with additional commands for manipulation of data files. For multiuser applications on local area networks, the product provides file- and record-locking mechanisms, multilevel password protection, and data encryption. For developers, dBASE III PLUS has a source language encrypter, linker, runtime interpreter module, and interface to assembly language subroutines. An optional interface provides easy linkage to programs written in C. End users may enter commands directly or use the assist mode with its point-and-select, pull-down menu structure. A simple, menu-driven source code generator is included for single file applications.

In the single-user mode, dBASE III PLUS demands a minimum of 256KB on a dual-floppy disk or a single-floppy and hard disk IBM PC, PC/XT, PC/AT or 100-percent compatible machine. The 256KB configuration is a tight fit, requiring DOS 2.x with only four buffers in CONFIG.SYS and a special dBASE CONFIG.DB file limiting several program parameters. Under DOS 3.x, single-user operation calls for 384KB.

For local area networks the server must be a PC, XT, AT, or compatible with floppy and hard disks and 640KB. The network operating system has to be DOS 3.1 or compatible, including Novell's Advanced NetWare/86 Version 1.01 and 3COM's 3Plus. Workstations must have 384KB and at least one floppy disk. Additional workstation memory is required for IBM PC network messenger, receiver, and redirector stations.

Each dBASE III PLUS package includes a network administrator program, dBASE ADMINISTRATOR, and one network access program, dBASE ACCESS, at a list price of $695. A separate LAN Pack provides complete documentation and dBASE ACCESS for three additional workstations on the network for a list price of $995. The system started shipping in January 1986, and upgrades are available for current users of dBASE III.

dBASE III PLUS is copy protected using SoftGuard's SuperLok, allowing direct installation on many hard disks in the single-user mode, but not on some network hard disks, notably those operating under Novell software. Workstations require a copy-protected key disk for ACCESS, or the program can be installed on a workstation local hard disk. This key-disk, copy-protection approach complicates network operating procedures and provides the unwary network administrator the opportunity for a frustrating installation process.

MICROCOMPUTER ROOTS

Although some other data managers for PCs have migrated downward from mainframes or minicomputers, dBASE III PLUS has its roots firmly embedded in microcomputers. dBASE has evolved from a command-driven file manager to a powerful relational data manager, and, according to Ashton-Tate, has an enviable worldwide installed base of more than 550,000 dBASE II and III users.

Earlier versions of dBASE have been used for almost every type of database application, due in part to its being one of the first data manager programs available for the IBM PC and compatibles. Powerful alternatives have since been developed, and many of the new features in dBASE III PLUS reflect Ashton-Tate's response to the competition.

Because of its microcomputer background, dBASE III PLUS interfaces well with DOS. The RUN command executes DOS commands such as DIR and COPY, COMMAND.COM, and other .EXE and

FIGURE 1: *Interfile Relationships*

```
. SELECT 2
. USE AUTHOR INDEX AUTHOR

. SELECT 1
. USE ARTICLE INDEX ARTICLE

. SET RELATION TO UPPER(AUTHOR_LN+AUTHOR_FN) INTO AUTHOR
. DISPLAY STATUS
```

```
Currently Selected Database:
Select area:  1, Database in Use: C:ARTICLE.dbf   Alias: ARTICLE
    Master index file:  C:ARTICLE.ndx  Key: STR(VOLUME,1,0)+STR(NUMBER,2,0)
    Related into: AUTHOR
    Relation: UPPER(AUTHOR_LN+AUTHOR_FN)
Select area:  2, Database in Use: C:AUTHOR.dbf   Alias: AUTHOR
    Master index file:  C:AUTHOR.ndx  Key: UPPER(AUTHOR_LN+AUTHOR_FN)
```

The SET RELATION TO command relates the Article file to the Author file through the author's last and first names (concatenated and converted to uppercase.) As the Article file is scanned, the Author file will be automatically positioned to the appropriate record, thereby making data, such as the author's address and phone number, available.

.COM programs and batch files. Parameters are passed on the command line to the executed program or batch file. The RUN command can be used at the interactive dot prompt or from within dBASE programs. A common use of this feature is to embed a communications program within a dBASE application. When the application is ready to connect to another computer for data transfer, the communications program is executed directly or through a batch file. Programs executed with RUN can exist anywhere in the DOS directory tree as long as the DOS environment contains a path to them and COMMAND.COM is available on the drive specified by the DOS COMSPEC parameter.

The DOS interface also allows the user to install a favorite text editor for command file programming and a separate word processor for editing of variable length *memo* fields. The names of the programs to be used are placed in the CONFIG.DB file with commands TEDIT=<editor file name> and WP=<word processor name>. This provides a closer coupling than RUN, because dBASE automatically passes the command file name to the editor and the name of a temporary file containing memo field text to the word processor.

No specific interface is defined for the return of data to the dBASE application from programs executed by RUN. However, a general purpose database file may be used to append text lines from an external program's output file. The dBASE application then is able to parse the lines in this file.

Binary files of up to 32,000 bytes each, produced from assembly language programs, may be loaded and called from within dBASE III PLUS. Individual files may be loaded and released as long as no more than five are in memory at the same time. Additional memory above the 256KB minimum is required for these files and should be reserved with a MAXMEM statement in the CONFIG.DB file to prevent loaded modules from being overwritten when RUN executes external programs. The CALL statement accesses the loaded binary files and may pass an expression or dBASE memory variable address.

dBASE's roots in microcomputers and DOS are the source of one major handicap. DOS files and I/O have been used to manage all of the dBASE file types, and the DOS limitation of 20 files (including those reserved by DOS) that can be simultaneously open per process is rapidly reached in large or complex applications.

This file count restriction can be alleviated somewhat by grouping programs into procedure files. Up to 32 subroutines identified by the key word *procedure* may be combined in a procedure file, only one of which may be open at a time. Whenever the file is opened, dBASE must identify the starting position for each subroutine in the file, creating some processing overhead. Procedure files can be used to offset some of the DOS file limitations, but a penalty is paid in speed if they are frequently opened and closed.

Other data managers have superimposed their own custom file management approaches on top of DOS to provide freedom from this restriction, but these methods also have disadvantages due to their unconventional use of the DOS file structure.

Developers who need to find out the operating environment of the target machine executing dBASE can choose from several functions. Function calls can retrieve the name of the operating system, the dBASE III PLUS version, the number of available function keys and their labels, available space on the default drive, and the DOS environment parameters such as COMSPEC or PATH.

DATABASE DESIGN

In dBASE III PLUS, data are stored in files of fixed-length records, with optional auxiliary files for variable-length text linked to the main file through memo fields. Separate index files establish logical sequences on data files and can use complex formulas on combinations of fields and virtual fields.

Ten work areas are available to open data files with associated indexes, screen formats, and filters. Linkage can be established between data files in different work areas to implement features of the relational model of data management. As the master file is manipulated, the subordinate file is automatically positioned in response to the content of the current record in the master file. dBASE III PLUS goes beyond a simple field-linkage model, because complex interfile relationships between two database files can be established using formulas on combinations of fields and virtual fields in both files. This is a powerful feature for data retrieval that often obviates generation of intermediate files through joins.

A simple example of files related through a formula is shown in figure 1. The database files are opened with their associated indexes, the Article file in work area 1, the Author file in work area 2. The formula for the index on the Author file concatenates the last and first name fields and takes the uppercase of the result. (The uppercase function is often used in index formulas to make data retrieval insensitive to alphabetic case.) As a scan is performed of the Article file, dBASE automatically positions the Author file to the corresponding record. Similarly, the relationship could be changed to operate from the coauthor's name in the Article file. Automatic retrieval of both author and coauthor addresses is not possible, because only one relationship is allowed per work area. This is a significant limitation that requires substantial coding to overcome for many applications, such as those with several data files related to a single master employee file. However, multiple files can be related in a chain in which the first file relates into a second file, and the second file relates into a third file, etc.

Formulas for relationship definitions can be quite complex and data de-

pendent. Numeric field data may be arithmetically combined, converted to character, and concatenated with converted dates, portions of other fields, or literal values. For example, a relationship formula could determine which tax rate record to extract from a tax table file based on a threshold calculated from income value in the primary file.

The implementation of index operations in dBASE III PLUS is one of its strongest features. Index files are of the B+tree type, and the formula used to define the sequence may operate on fields, portions of fields, and virtual fields up to a maximum of 100 characters. Functions may be nested in the indexing formula to convert dates to strings, extract portions of strings, and convert numeric formulas to strings for concatenation into the index. The conditional IIF (immediate if) function may even be used within an index file formula to choose argument data based on record content. The IIF function takes a conditional expression followed by two value expressions and returns the first value expression if the conditional expression evaluates to true, and the second value expression otherwise. For example, the following command creates an index that combines data-dependent home or work zip codes into a single sequence:

```
INDEX ON IIF (MAILFLAG = "H", HOMEZIP,
    WORKZIP) TO ZIPINDEX
```

Each data file may have an unlimited number of index files associated with it, and up to seven index files for an active file may be open at one time. All open index files are updated automatically when fields are changed in the data file, and index files may be created or reestablished at any time. An index file may be designated UNIQUE at creation, and entries will point only to the first occurrence of records that have duplicate keys.

Facilities are available in dBASE III PLUS for saving retrieval scenarios for later use. Once work areas, files, indexes, relationships, and field lists have been established for a specific scenario, the set-up information can be saved in a *view* file. A view can be created interactively or captured with the CREATE VIEW FROM ENVIRONMENT command. A view file contains the names of the open database files, any open index files, associated work areas, interfile relationships, and selected fields from each data file. One screen format file name and one filter condition can also be saved. The view can be reestablished using SET VIEW TO <viewfile>.

This concept of views into a database is new to the dBASE line, and provides a powerful applications development tool. The designer can define a database file structure, indexes, and relationships, and can provide a data edit screen without programming. Care must be taken to ensure that file relationships are one-to-one or many-to-one because dBASE III PLUS has no capability for automatic retrieval of duplicate records in one-to-many situations. The field list must also be established to prevent changes to fields used in indexes that form the relationships. These constraints are not necessarily overly restrictive for many applications, especially in situations where data retrieval or maintenance of relatively static records is the primary operation.

One suitable application might be a database of personnel records with data files indexed on employee number. Medical benefits can be kept in one file, salary information in another, resume and job descriptions in others, etc. Custom programs will need to be written to handle the more complex

events such as adding or terminating an employee, but daily maintenance of non-key data and routine reporting can be set up with a series of views.

In addition to the view file and associated commands for establishing a database environment, an interactive query feature helps the user create and save nested conditional queries. A *query* is a formula defining a subset of the data in a database. It is considered to be a filter condition that can be saved in a file and then invoked with SET FILTER TO FILE <queryfile> or SET FILTER TO <condition>. Retrieval scenarios may be predefined in terms of view and query files and easily invoked for periodic report purposes.

dBASE III PLUS file structure is based on fixed-length data elements and is poorly suited to applications involving variable length text. dBASE III PLUS alleviates this problem with the memo field. Fields of this type contain pointers into an associated text file, which is linked automatically to the main file.

Data space in the associated memo text file is allocated in 512-byte segments chained together as necessary to provide storage for the individual memo fields. Only one associated text file is required even if more than one field in the primary database file is of the memo type. Data are entered with the dBASE III PLUS word processor (or one that is linked to the data manager) and can be displayed or printed only with the DISPLAY, LIST, and ? commands (the single question mark means show) or within the report writer. Because the dBASE language has no provision to move memo field text through memory variables, it cannot be manipulated, searched, or checked under program control. Reports programmed without using the report writer cannot print text data from memo fields. These restrictions limit the use of these fields.

DATA ENTRY, UPDATE, INTEGRITY

Entry of data into a multifile database is not as simple as data retrieval. Because of the method of linking files through indexes on fields, empty records cannot be automatically inserted into related files for data entry without disrupting the record positions. Editing of data fields involved in the linkage formulas is also certain to cause problems. A full-screen data form may be easily defined and saved for single file-data entry and multiple file-data retrieval, but full-screen data entry to multiple files with simultaneous table look-up and data checking usually requires a substantial amount of programming effort.

dBASE III PLUS assumes a full-screen edit approach for data entry. An internal default data entry screen is provided for each data file based on field definitions in the file. The underlying concept of all dBASE data entry is that fields are defined on the screen using the @ <row>,<col> GET <variable> commands and then collected simultaneously with the READ command. The user enters data to the fields on the screen with standard dBASE cursor commands and can move about the screen until the last field is exited by pressing either the Enter key or other special keys such as Ctrl-End. At this point, the data are made available to the data entry program. They may be entered directly to data file fields or to program memory variables.

A basic flaw in this approach is that data entered by the user are not available until READ is executed. Automatic table look-up is not provided, and the programmer cannot use the data from individual fields as they are entered. A READ can be executed after each field is defined with @...GET, but this interferes with the full-screen editing capability. An INKEY() function traps keystrokes, but it bypasses editing functions normally supplied by dBASE. Custom data entry screens with on-screen calculations and table look-up require significant programming skills.

The screen implemented for the sample application is a good example of a custom screen. (The sample application was developed by *PC Tech Journal* editors for this series on data managers. For a complete description, refer to "Sample Application Specifications," August 1985, p. 48. The article is also available for downloading on PCTECHline.) Properly implemented, more than 200 lines of dBASE program code were required to support the data checking, table look-up, and entry of data into multiple related files. Some of the code and logic allowed the program to be used for data editing as well as entry.

For applications in which the dBASE *format* file approach is acceptable, attractive custom screens can be generated quickly with the MODIFY SCREEN command. An interactive screen painting facility allows the designer to move fields around, insert prompt text, draw boxes, and establish data range and field editing specifications. The painted screen automatically produces a special format file containing standard dBASE program statements to collect the data from the screen. The only statements allowed in a format file are @...SAY..., @...GET... commands or up to 32 READ

statements, which cause dBASE to execute the file as a multiple screen program. Each READ defines the end of a screen, with the PgUp and PgDn keys used to swap screens. The screen generator creates a file with the extension .SCR. The format file may be edited the same as any other dBASE program file, but the .SCR screen definition file can be changed only with MODIFY SCREEN, causing the format file to be recreated entirely. The screen generator saves substantial programming by creating the @...SAY/GET statements for incorporation into custom programs.

Data integrity is the responsibility of the user or programmer. dBASE III PLUS contains no automatic transaction processing or audit history feature, but data file headers are updated with the date of last file modification, retrievable via a function call. Applications that require transaction processing can be developed using temporary data files as input buffers, with posting accomplished separately. This technique also eases the problem of entry into multiple related files, because all fields can be defined in one file for data entry, with the posting process performing the updating of the related files.

STRUCTURED LANGUAGE

The dBASE III PLUS language provides commands to support structured programming constructs, create and manipulate data files, accept data entry, display and edit data, interface with the user, and communicate with external programs. dBASE is an interpreted language, and a compiler is not provided by Ashton-Tate. Third-party compilers are available for earlier versions of dBASE, but they have not yet implemented the new features of dBASE III PLUS. An encrypter and linker are provided with the package for source code compression and protection. The dBASE III PLUS program can execute combinations of raw, encrypted, and linked source code. A RunTime+ module can execute encrypted, or encrypted and linked, code and is intended for turnkey applications. Some reasonable restrictions apply to code that is intended for execution by RunTime+ modules. They are not copy protected.

Structured programming is implemented via DO WHILE/ENDDO loops, with LOOP and EXIT commands for control within loops, IF/THEN/ELSE and DO CASE/CASE/OTHERWISE/ENDCASE conditionals, and DO <subprogram file>/RETURN for subroutines. Parameters can be passed to and from subprograms. Each program/subprogram is contained in a separate file unless grouped in a procedure file. Event trapping and branching is handled by the ON ERROR/ESCAPE/KEY <command> settings. When set, an error causes an immediate execution of the specified command, which may call a separate program. Two commands, RETURN and RETRY, return control to the calling program. The first returns control to the statement after the call, while the second reexecutes the calling command. Error trapping occurs for errors identified by dBASE III PLUS, not for errors at the operating system level.

Up to 256 temporary memory variables may be simultaneously active, and storage for variables may be adjusted in the CONFIG.DB file. Public and private memory variables can be established for all data types except memo, and are implicitly declared when data are assigned to the variables. Data assignment to memory variables is via the STORE <value> TO <variable>, which may be shortened to <variable> = <value>. Memory variable names are up to 10 characters in length, as are file field names. Ambiguities between memory variables and field names can be resolved by prefixing the name with M —> (for memory), or the data file alias for field names. Memory variables may be saved to and restored from files. Assignment of data to fields in database files is accomplished with the command REPLACE <field name> WITH <value>. Incidentally, this command has no short form.

The private attribute for memory variables is implemented in an unusual fashion; variables declared private remain available to subprograms called from the program declaring the variable, but are not available after the return to upper levels. In effect, a subprogram can protect the variables of the programs above it, but cannot protect itself from subprograms it calls. Public variables are available to all programs at any level, including the direct command level. The default attribute is private, so all variables at and below the current subprogram level—except those declared public—are released upon return to the higher-level calling program.

More than four dozen parameters may be set on, off, or to specific values to modify the internal dBASE environment. For example, SET DEFAULT TO <drive> changes the default drive within dBASE (but not the DOS default drive), SET COLOR TO <value> controls screen display attributes, SET ESCAPE ON/OFF permits or denies the user program interruption privileges,

and SET FORMAT TO <filename> opens a data entry screen file. From the interactive level dot prompt, the command DISPLAY STATUS shows parameter settings, but these settings cannot be determined from within command files. For large applications in which several programmers may be developing separate modules, the inability to test the dBASE environment upon subprogram entry means that programmers cannot determine which parameters must be reset within the subprogram.

dBASE III PLUS offers several powerful data file manipulation commands, which can process an entire file with conditional subset selection within the command. For example, the command

```
REPLACE REST VENDORNAME
  WITH 'ACME',
    UNITPRICE WITH UNITPRICE * 1.1
    FOR ITEM = 'PART#3126'
    WHILE VENDORNO = '123'
```

begins at the current record and continues, record by record, until the end of file is reached, or until the VENDERNO field changes from the value 123. Whenever a record is encountered in which the item field contains the value PART#3126, the UNITPRICE field value will be increased by 10 percent, and the VENDORNAME field changed to ACME. When multiple files are related and a field list has been established with the SET FIELDS command, REPLACE can change values in more than one file at a time. Care should be taken not to change values in fields that would affect the active index sequence, because this will disrupt the logical sequence of the records during the execution of the REPLACE command, and records may be inadvertently skipped.

Database files may be created under program control from other database files by copying all or selected fields from an existing file. In addition, the field definitions of a database file may be stored as data in another file with the COPY STRUCTURE EXTENDED command and modified in the same way as any other database file; a new database file can be created with the CREATE FROM command.

In addition, JOIN and TOTAL cause the creation of database files. The latter creates a summary database file from a sorted or indexed file, with numeric fields automatically totaled into a summary record for groups of records having the same key field.

Nearly six dozen functions are provided to test the environment, modify memory variables, perform mathematical and format transformations, con-

vert data types, and manipulate dates. Two of the more interesting are the IIF(<logical expression>,<result if expression is true>,<result if false>) function mentioned above, and TRANSFORM, which converts numeric and character data through a picture format; it inserts commas, dollar signs, and similar characters in the displayed value. This function can be used in the report writer to make the numbers more attractive, but the transformed values are no longer numeric and cannot be automatically totaled or subtotaled.

dBASE III PLUS uses floating-point internal representation for numeric values, providing 15.9 digits of accuracy for arithmetic computations (the user can depend on 15-digit accuracy and can sometimes achieve 16). To limit the incorrect comparison of numbers caused by the inexact floating-point representation, numeric comparisons are performed only to the 13th digit. Rounding errors are still possible and may affect comparisons after about 2,000 iterations. Programs that save running totals should replace the value with the combined VAL(STR(<number>)) within the 2,000 iterations to maintain accuracy in comparisons. This is an inconvenience in business applications that is not found in data managers with character or binary-coded decimal numeric data types and arithmetic.

A ROUND function is provided, but negative values are rounded to the next integer in the positive direction; therefore, rounding should always be accomplished on the absolute value of the number. The MOD function performs modulo arithmetic; when one or both of the arguments is negative, however, the result should be tested because it may not be what is expected.

Because dBASE is an interpreted language, sophisticated macro expansion is possible. Simple macro expansion using the & operator is useful for parameterizing programs, as in

```
USE &DDRIVE.DATAFILE INDEX
    &IDRIVE.INDXFILE
```

where the memory variables DDRIVE and IDRIVE contain values such as C: or B:. The period delimits the end of the memory variable name to prevent ambiguities. Sophisticated macros may generate full dBASE commands, as in &DOIT, which might expand to

```
DO SUBPROG WITH '.T.', PARM2, VALUE
```

This type of macro is not supported by the RunTime+ interpreter and probably should not be used if the code is ever going to be maintained.

dBASE III PLUS provides a tool called a *data catalog* to organize files in an application. A catalog file is a database file with a .CAT extension and a specific structure. dBASE automatically opens a catalog in work area 10 and maintains its records in response to the process of creating and erasing files associated with the application. Fields in the catalog record for each file contain the path, file name, alias, file type, a user-entered title, a code relating files to the data file from which they were created, and a user-specified tag. The file types and default file-name extensions that are automatically maintained in the catalog are the following: data (.DBF), view (.VUE), format (.FMT), index (.NDX), label (.LBL), query (.QRY), report form (.FRM), and screen (.SCR).

When a catalog is open in an application, it may be queried during interactive command operations to determine available files applicable in the current context. For example, after opening a data file with the USE command, the command SET INDEX TO ? displays a menu of all cataloged index

files previously created from the open data file. The catalog concept is useful for managing the multitude of files usually created for an application.

An interpreted language has a substantial advantage over compilers during the debugging process, and dBASE III PLUS provides features to enhance this advantage even further. Commands entered at the dot prompt are saved in a last-in, first-out history buffer and can be recalled, edited, and reexecuted. The history feature may be set on or off and the size of the buffer changed with a SET HISTORY command. The default size provides space for 20 commands. A feature called DOHISTORY traps commands executed from program files into the history buffer for analysis. Command file programs can be executed in single-step mode and observed during execution with SET ECHO and SET DEBUG facilities.

Programs can be suspended and resumed with breakpoint SUSPEND commands that are embedded in the program, or the Escape key may be used to interrupt operations. While the program is suspended, the current status of all memory variables, file positions, and parameter settings is available for review. The suspended command file cannot be modified, and any modifications to memory variables should be attempted only with caution. The suspended program either may be restarted with the RESUME command, or it may be canceled.

Performance issues are important when discussing an interpreted language. A compiler would provide substantial speed increases for many dBASE programs. Programs using the data file manipulation commands wherever possible to process large amounts of data do not show as much improvement because disk I/O will probably be the limiting factor. dBASE III PLUS performance suffers most when many memory variables are manipulated in loops.

SORTING AND INDEXING

The two methods used to impose a sequence on database files in dBASE III PLUS are sorting and indexing. Historically, dBASE sorting has been excruciatingly slow, but dBASE III improved the sort performance by orders of magnitude, and the indexing performance substantially, so that sorting became a viable alternative for some operations. The performance improvement in dBASE III PLUS is claimed to be a factor of 10 over dBASE III for indexing, and a factor of 2 for sorting. This relegates sorting to the backseat again for all operations except those that require processing the entire file in sequence.

If an index sequence is required for data maintenance operations as well as for reporting, then the index should be maintained as data are added and updated. When a sequence is necessary for reporting only, the time taken to create the index at report time may be offset somewhat by the operational simplification of maintaining one less index file.

Indexing formulas can combine fields and functional transformations of fields, whereas sorting is on a field-by-field basis to a maximum of 10 fields. However, creating an index for reverse alphabetical sequence would be difficult, whereas the sort can do this easily, optionally ignoring alphabetic case.

Space requirements for sorting and indexing are not easily compared. Sorting creates a copy of the file, so the necessary storage can be determined. Storage requirements for a B+tree index can only be approximated, and the formula depends on key size and number of records. Index files can exceed

the size of the data file if the key is lengthy, but complexity of the key formula has no effect on index file size.

REPORTING

Other data managers incorporate data selection and organization in the reporting process, but in dBASE III PLUS, the functions of setting up the data for reporting (opening and sorting files) are separated from report production. Sequencing and filtering operations, with indexing, sorting, joining, queries, and custom programs, are usually performed prior to report production, especially when the internal report writer is used. The command to execute a predefined report or label form may contain FOR and WHILE clauses to select data for reporting, but file opening and indexing or sorting must have been previously accomplished.

The report generator produces column-oriented reports with a maximum of two breakpoint levels. The report form file is generated interactively with the command CREATE REPORT <report form file name> and can be edited with MODIFY REPORT. One or more data files must be open when defining or modifying a report form, and the field list is available as a pop-up menu.

Report files produced by the report generator are invoked with the REPORT FORM <formname> command, and options in the command syntax can establish or modify conditions for headings, output device, and data selection. Data can be gathered from more than one file, and previously defined query filters remain in effect.

The report generator provides automatic page numbering and dating. Multiline page and column headings can be specified, and margins, page length, and line spacing set. Page headings cannot contain variable data from functions or from the files being processed. An optional heading line, specified when the report is executed, may contain functions such as TIME(). The page heading text lines are automatically centered. The location of the page number and date cannot be adjusted, and footers are not implemented. Headings and page breaks may be suppressed at report execution time.

Up to four lines of heading text may be entered for each column defined in the report. A report may contain 24 columns, and columns may contain combinations of fields. dBASE III PLUS provides automatic word wrap if a column is set narrower than the data field, and a semicolon may be used to force a carriage return and line feed within a column. This can be used to stack address lines, for example.

Fairly sophisticated reports may be developed if the user learns all the nuances of the report writer. Functions can modify data as they are output, and TRANSFORM can alter presentation format. dBASE III PLUS has no provision for presenting large numeric values with commas while retaining the ability to total and subtotal. This reduces somewhat the utility of the report writer for many financial applications.

Report output may be directed to a screen, printer, or file. However, the user cannot specify a printer set-up character string. The printer must be set up by using other output commands prior to executing the report.

The same @ <row>,<col> SAY <value> [picture] commands used for data entry and screen output can also be used to program custom reports of any complexity. The programmer is responsible for all page, line, and column counts, although the PROW() and PCOL() functions are used to determine the current print position.

A substantial deficiency in this method of producing custom reports is the inability to direct the output of @...SAY... commands to a file. Custom reports destined for files can use only the ? and ?? commands, which simply append data to an output stream. A single question mark produces a carriage return and line feed before printing, and a double question mark suppresses them. Functions, memory variables, and fields can be output with the question mark command, and the TRANSFORM function can be used for formatting, but this is an awkward and primitive alternative that should not have to be used in too many circumstances.

Mailing labels are generated with a separate feature specifically designed for the purpose. The creation and invocation of label forms is similar to that for the report writer. The label size and number across can be specified or chosen from a list of standard sizes. Line contents are defined using data from fields, literals, and functions. As a convenience, fields can be separated by commas to cause the output to be trimmed of trailing blanks and a space inserted between them, as in **firstname, lastname**. The IIF function can be used to select output data based on values of other data in the record, and data can be gathered from multiple linked files. (A program to print labels for the sample application is shown in listing 1.)

When executed, the label program produces optional sample labels of

asterisks for printer alignment, and blank lines are suppressed automatically. The output can be directed to the screen, printer, or text file.

CRASH RECOVERY

dBASE III PLUS provides no features to protect data in the event of power loss or other equipment failure. Data record counts and field definitions are maintained in the file header area of each file and may be damaged or corrupted by system or hardware failure. The only sure way to protect data is to perform systematic operational backup of files. In emergencies, techniques are available for programmers to replace damaged file headers, and data can be retrieved by stripping away the header and appending the resultant fixed-length data into a new database. These techniques may be used only on unencrypted files. Linked memo fields in the .DBT file are difficult to restore because updated text segments are replaced with new segments elsewhere in the file and are not physically deleted unless a COPY or PACK is performed. The header and memo file internal structures are detailed in the documentation.

Index files often lose synchronization with the associated data file because of user or programmer oversight. The index formula is stored in the index file header area, and the REINDEX command will cause the index B+trees to be rebuilt for all open index files in a work area. Applications should include a utility program to reproduce essential indexes from scratch.

MULTIUSER CAPABILITIES

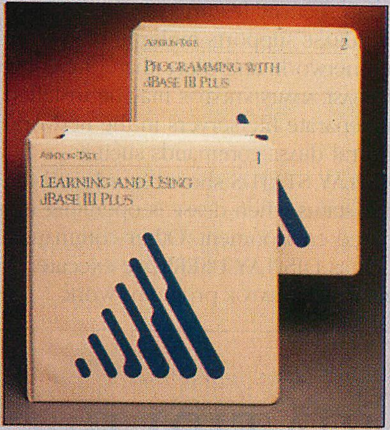
The dBASE III PLUS package contains programs necessary for installation and operation on local area networks. The networks supported require 8088, 8086, or 80286 CPUs and DOS 3.1 or higher. For a Novell network, Novell Advanced NetWare/86 (version 1.01 and higher) and the NetWare Server Board are needed. The IBM PC Network calls for the PC Network Program (version 1.0 and higher), and one Network Adapter Card for each workstation. The file server must have 640KB of memory and a hard disk. Workstations require at least one floppy disk. Workstations on a Novell network need 384KB of memory. IBM PC Network Messenger stations require 640KB, Receivers 512KB, and Redirectors 448KB.

A dBASE ADMINISTRATOR program is installed on the network server, and dBASE ACCESS is installed at each workstation. The ACCESS program is copy protected with SoftGuard's SuperLok and

dBASE III PLUS OVERVIEW

dBASE III PLUS, version 1.0
Ashton-Tate, 20101 Hamilton Avenue, Torrance, CA 90502-1319; 213/329-8000

Product type. A data management and applications development system for general use with stand-alone or multiuser local area networks.
IBM PC environment. PC, PC/XT, PC/AT, or 100-percent compatible running DOS 2.0 or higher with 256KB of RAM, two 360KB floppy disk drives, or one floppy drive and a fixed disk, and a monochrome or a color monitor. The system configured with 256KB is restricted to DOS 2.x with the minimum number of CONFIG.SYS buffers and the minimum number of parameters in the dBASE III PLUS CONFIG.DB file. 384KB is needed to run DOS 3.x.
Other environments. No other environments are supported.
Network support. DOS 3.1/IBM PC Network Program or 100-percent compatible; 3Com 3Plus Operating System; and Novell Advanced NetWare/86, 1.01 or greater. A network server/workstation requires an IBM PC, XT, AT, or 100-percent compatible with a minimum of 640KB of RAM, a monochrome or color monitor, one 360KB floppy disk, and one fixed disk. A network workstation requires an IBM PC, XT, AT, or 100-percent compatible with a monochrome or color monitor and one 360KB floppy disk. Novell workstations require 384KB. IBM PC Network Messenger stations require 640KB, Receivers 512KB, and Redirectors 448KB.
Copy protection. The software is copy protected using Softguard's SuperLok, but can be installed on many fixed disks. Access modules for LAN-shared operations require a copy-protected key disk at the workstation.
Documentation. The documentation for this product is substantial, weighing 9.3 pounds, and includes an on-disk tutorial. Ten chapters in the manual are about the interactive mode, and 15 chapters discuss programming. In addition, a comprehensive reference section, a guide to managing the networked version, a command and function quick reference, and a "Getting Started" booklet are included.
User interface. dBASE III PLUS uses an interactive command mode to communicate with users. An assistant mode with pull-down menus also is



provided. The product runs under a structured programming language.
Help facilities. On-line help describes individual commands and syntax. The assistant mode provides a pull-down menu command generation user interface. The status line displays prompts as menu choices are scanned.
File capacities. The software allows 4KB per database file; 512KB per memo file; 128 fields per record; 1 billion records per file; and 2 billion bytes per file. A maximum of 20 files of all types can be open simultaneously (this is due to the DOS limit per process), and 10 database files can be open simultaneously (a database file with memo fields counts as two files). A maximum of 7 index files and 1 format file can be open for each active database file.
Field types and capacities. dBASE III PLUS allows 254 bytes per character field; 19 bytes per numeric field; 8 bytes per date field; 1 byte per logical field; and 5,000 bytes (or external word processor capacity) per memo field.
Data entry. The default field-per-line data entry screen is defined by the field specifications of the file, but can be reorganized using the screen format file. The table-view browse command enters and modifies data.
Applications development facilities. Full turnkey system development is supported through programming. The applications generator produces automatic menu-driven program code for single-file applications, and the advanced generator produces menu code for user-specified commands. The applications generator is written in the dBASE III PLUS programming language; the source code is not provided. The software package includes the RunTime+ semi-compiler system, which can be used for code encryption and linkage of developed applications programs. Combinations of encrypted, linked, and source code can be executed. Runtime modules are available that can execute the encrypted code without dBASE III PLUS.
Security. Password security can be programmed into applications in the stand-alone mode. Multiuser installation provides for multilevel password-protection schemes and data encryption. Multiuser installation also can be accomplished on a single-user machine if password and encryption access features are desired.
Access to system facilities. External programs (COMMAND.COM and batch files) can be run from the interactive prompt or from program files.
Queries. Queries define subsets of files or related files by filter specifications using nested formula conditions of fields and virtual fields. They can be stored in query files for retrieval later either interactively or under program control.
Reporting. Report formats can be stored and edited. The software supports columnar report layout of fields per report line. The appearance of reports can be tailored using functions, virtual fields, report column word wrap, as well as sub and sub-sub total breaks. A special mailing label report form and file type is included. The reports and labels operate on a subset of the file records, which is defined either by report invocation command or preestablished query. Output can be sent to the screen, a file, or a printer. Special report formats are available through programming.
Utilities. The catalog feature provides a dictionary of data and operational files. Data file header specifications support damaged file data recovery.
Data compatibility. The program reads and writes fixed-length ASCII, delimited ASCII, PFS, Multiplan SYLK, Lotus 1-2-3 .WKS, and DIF files.
Distribution. Distributors and dealers. Registered dBASE III PLUS packages are upgraded directly by Ashton-Tate.
Price. $695; upgrade from dBASE III, $140 (free to users of dBASE III purchased after October 1, 1985); free upgrade from dBASE III developer's release version; CTOOLS, $89.95.
Support. Phone support is provided.
—Dave Browning

uses the key-disk approach, or it may be installed on a workstation local hard disk. dBASE ACCESS programs are serialized to prevent simultaneous network use by more workstations than there are authorized access modules. The PROTECT program is a separate utility included with the ADMINISTRATOR and is optionally used to control dBASE log-ins, file and field access security, and data encryption. Only data files and index files can be encrypted. The text files linked to data files for storage of memo fields are not encrypted. The ADMINISTRATOR and PROTECT programs may be installed in a single-user environment if the user desires the encryption and data access security features.

dBASE supports multiple file servers in a network, and more than one copy of dBASE ADMINISTRATOR may be installed on separate file servers in the network. Several dBASE commands such as DISPLAY STATUS show record- and file-lock status when dBASE is operating in a shared environment. Other commands such as DISPLAY USERS are executed by the ADMINISTRATOR program. Workstations may direct printer output to local or network printers.

The PROTECT program establishes and maintains security in the network dBASE environment. A dBASE log-in is maintained for each user, access privileges to files and fields are assigned, and data encryption is enabled. Users and files are assigned to groups, and each group uses a different key for encryption. Within each group, individual users can be given different categories of access to the application's data files. A password system file DBSYSTEM.DB is built and maintained by the PROTECT program and stored in an encrypted form. A hard copy of the PROTECT menus can be made during the security set-up process for reference when users forget their passwords or other log-in values.

Simultaneous data access by multiple users requires management to avoid collisions and deadlocks. Files are opened in either exclusive or shared modes. Files opened for exclusive use do not require concern for locking activities, because only one user may access the data. If the SET EXCLUSIVE parameter is on, then files automatically default to the exclusive mode when opened. When the parameter is off, the files are opened for shared mode. Commands that operate on entire files, such as BROWSE, REPLACE ALL, and SORT, cause dBASE to lock the file automatically before executing the command. If the file cannot be locked, an error is generated that can be trapped by the ON ERROR setting. The RETRY command can be used to attempt the command execution again.

When @...GET/READ commands or single-record REPLACE commands are used, the programmer must lock the record, redisplay the current data (which may have changed since the time the user first viewed it for editing), change the data, and unlock the record. Locking of multiple records or records in multiple shared files must be programmed carefully to avoid file deadlock—that is, two user programs trying to lock overlapping sets of files or records, with each program capturing a portion of the files or records in the shared subset. The dBASE file- and record-lock commands do not support specification of more than one item at a time for locking, so the programmer must include logic in order to detect and break the deadlock condition.

When the dBASE full-screen EDIT or CHANGE commands are executed, the user at the keyboard can control the lock status of the current record by pressing Ctrl-O. dBASE will show the

lock status in the status bar. Of course, operational procedures must be enforced to keep users from leaving records locked unnecessarily.

Programming commands are also available to test user access authorizations from within programs. Program logic can then implement additional security by avoiding display of menu choices or functions for which the user does not have authorization. Programs can execute the LOGOUT command when the user finishes.

dBASE III PLUS ignores network-specific features in programs when executed in a single-user environment, so applications can be designed and programmed for the multiuser mode from the beginning.

SUBSTANTIAL DOCUMENTATION

The dBASE III PLUS documentation is substantial. An attractive storage case of the standard height and depth contains two loose-leaf volumes, several booklets, and weighs in at 9.3 pounds.

The two volumes of main documentation are divided into five sections. Volume 1, *Learning and Using dBASE III PLUS*, includes a 10-chapter section "Learning dBASE III PLUS," which uses the assistant mode and a disk of sample files to provide a hands-on tutorial.

The reference section, "Using dBASE III PLUS," is the largest of all the sections and will be used extensively by programmers and end users alike. The overview chapter in this section provides program technical specifications and limits, describes the different types of files used by dBASE III PLUS, lists keyboard navigation for full-screen operations, and explains the use of the CONFIG.DB file to customize default parameters. This chapter also provides an excellent summary of the differences between dBASE III PLUS and the previous dBASE III versions. The rest of the section includes chapters on user interface procedures, key words, commands, functions, utilities, and error messages. Command descriptions do not start on a fresh page for each command, and page header guide words are not provided. Key words, such as SYNTAX, USAGE, EXAMPLES, DEFAULTS, and SEE ALSO, are set off to the left of the text, and the command name is highlighted in blue. The reference material is detailed and informative.

The utilities section describes the differences between dBASE II and III. It also provides instructions for operation of the dCONVERT program, which helps move dBASE II applications to dBASE III. The error message section lists error messages with explanations and identifies the associated error number returned via the ERROR() function.

Appendices list the structure and contents of the sample files, list and describe the cursor control key operations, and provide technical layout of the .DBF and .DBT files. The complicated logic is also described for determining which conditions cause the BOF() and EOF() functions to be set when testing for beginning and end of file positions. A glossary of terms and a comprehensive index are provided.

Volume 2 contains a 16-chapter section, "Programming With dBASE III PLUS," intended to teach programming in the dBASE language. A checkbook management system application of more than two dozen files and programs is provided on disk and serves as study material for the programming tutorial chapters.

"Networking with dBASE III PLUS" provides information on network database applications management, operational considerations, applications security, network programming concepts,

and a reference section of dBASE commands and functions specific to network programming. This very technical section must be thoroughly understood for effective use of dBASE III PLUS in a network environment. The subject of network database applications development is complex and difficult, and this section needs to be expanded.

The final section, "Runtime+," presents the process of code encryption with the dCODE program and linkage of encrypted program files with dBLINKER. The use of the runtime interpreter dBRUN is also discussed, including the constraints imposed on programs intended for runtime applications.

The 53-page booklet *Getting Started*, also included in the documentation package, covers the mechanics of installation and set-up for various system configurations, including dual-floppy, hard disks, and LANs.

The *Applications Generator* booklet discusses in 41 pages the use of the dBASE program APPSGEN.PRG provided for automatic programming of simple applications. The errata sheets indicate that the program is provided in a code-encrypted and linked form for performance reasons, and that the directory of the applications generator disk is different from that listed in the booklet. This subtle change means that dBASE source code for the applications generation process is not available to the user, as was apparently intended. This is most unfortunate, because the applications generator program could have been tailored by developers for repetitious programming tasks. As it is, the lack of source code limits the usefulness of the applications generator program.

A *Quick Reference Guide* lists the dBASE language commands, and functions giving syntax. In addition, a small *Customer Support Guide* discusses the warranty and support provisions, provides reference addresses and telephone numbers, and emphasizes the need to register the package (which is further encouraged by a chance to win a $500 hardware prize).

Among several promotional and advertising inserts included with the documentation is an order form for Ashton-Tate's *TechNotes*. This monthly publication, which provides programming tips, known errors and workarounds, sample programs, questions and answers, and update policies, is well worth the annual $50 fee.

END-USER FACTORS

Ashton-Tate has tried to make dBASE III PLUS a product for developers and end users alike. Development of entirely customized applications is possible because the programming language has access to low-level functions such as INKEY(). The end-user interface consists of several full-screen, interactive commands, such as BROWSE or CREATE QUERY, which may be invoked through the assistant mode or from the dot prompt. These end-user interface commands can also be used within programs to avoid substantial programming effort. The most efficient method of applications development uses a combination of custom programming and the default end-user interface.

dBASE III PLUS arrives on eight floppy disks. The program itself, with help files and overlays, requires two system disks. The first is copy protected with Super-Lok, and a backup copy is provided. If the program is run from floppy disks, the files on the second disk must remain available for help files and overlays. Separate disks are provided for sample programs and utilities, the on-disk tutorial, and the applications generator program. The dBASE ADMINISTRATOR program for use with network operations takes up two more disks.

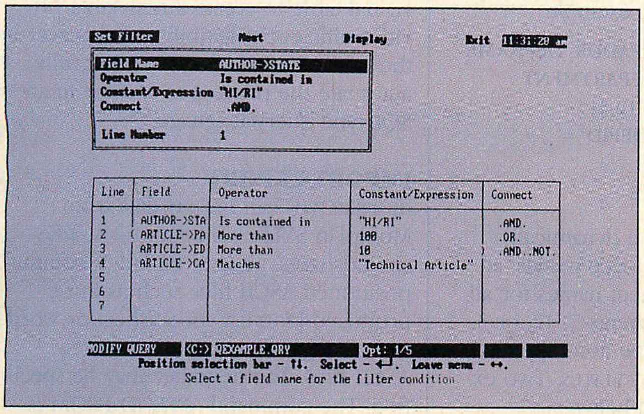
Special CONFIG.SYS and CONFIG.DB files are provided for single-user operation on a 256KB system. These files limit the number of DOS buffers to four and restrict the maximum default values for several dBASE parameters. DOS 2.1 must be used with 256KB systems.

dBASE uses the DOS path in the environment to look for configuration, overlay, and help files if not found on the default drive, so applications may be developed in separate subdirectories. The program will first look for the CONFIG.DB file in the DOS default directory; this allows alternate start-up default parameters to be configured for different applications.

A SET PATH TO command sets an internal path list for dBASE to search for existing files such as applications programs or the applications generator program. This setting does not override the existing DOS path and is not communicated to external programs that are called with the RUN command.

For networks, the ADMINISTRATOR program is installed on the network file server, and the ACCESS program is installed on dBASE system disk number one or on a local workstation hard disk. The dBASE program actually becomes ACCESS and is renamed by the installation batch file. ACCESS communicates with ADMINISTRATOR for security and network locking functions.

PHOTO 1: *Interactive Query Creation*



The CREATE/MODIFY QUERY command provides this interactive method of creating a filter condition that defines subsets of the data. Subsequent commands, such as REPORT, LIST, or EDIT, respect the filter condition in effect.

FIGURE 2: *Status Reflecting Filter*

```
. set view to qexample
. set filter to file qexample
. display status

Currently Selected Database:
Select area:  1, Database in Use: C:ARTICLE.DBF   Alias: ARTICLE
    Master index file: C:ARTLABEL.NDX  Key: STR(VOLUME,1,0)+STR(NUMBER,2,0)
                                    +UPPER(AUTHOR_LN+AUTHOR_FN)
Filter: TRIM(AUTHOR->STATE)$"HI/RI" .AND.(ARTICLE->PAYMENT> 100 .OR.
  ARTICLE->EDIT_PAGES >10).AND..NOT.ARTICLE->CATEGORY= "Technical Article"
    Related into: AUTHOR
    Relation: UPPER(AUTHOR_LN+AUTHOR_FN)

Select area:  2, Database in Use: C:AUTHOR.DBF   Alias: AUTHOR
    Master index file:  C:AUTHOR.NDX  Key: UPPER(AUTHOR_LN+AUTHOR_FN)
```

The DISPLAY STATUS command shows how the filter, established by the interactive query creation shown in photo 1, is stored as part of the view. The filter also can be set directly with the command SET FILTER TO <condition>.

QUERY LANGUAGE

The dBASE III PLUS query process is a mixture of features found in the approaches of relational algebra and calculus. The product offers no specific high-level query language such as SQL (Structured Query Language), but it does have features that allow the extraction of data from multiple files without the creation of intermediate tables. For the user who understands the structure of a database, many queries are straightforward, and the reporting commands allow additional selection of the set of data to be presented.

The concept of a *filter* on the data, which is used throughout dBASE, defines subsets of the data files currently open. The CREATE/MODIFY QUERY command provides a full-screen and interactive method of creating a filter condition, which may be saved in a file for later recall and modification. Once the filter condition has been established, subsequent commands, such as REPORT, LIST, or EDIT, respect it. One query filter condition may be saved with a view and involve fields from more than one file. Photo 1 shows one of the screens in the interactive process of creating a query filter condition. Figure 2 shows the status of the files and the filter condition after the two commands

SET VIEW TO QEXAMPLE
SET FILTER TO FILE QEXAMPLE

have been executed. The filter could also have been set directly with

SET FILTER TO <CONDITION>

which is often used in programs.

A query may become quite complex before the creation of intermediate files is needed; the query itself may require more than one command for implementation. Separate filters may be invoked for each of several related files, but the ability to refer to fields from multiple files in one filter condition makes this unnecessary in all but the most complex situations.

Additional conditions may be imposed to select the data subset during the reporting process. The SET FIELDS TO <field list> command specifies which fields from the open data files are available for subsequent use. The commands for data display, reports, labels, copy, join, sum, browse, and several others respect both the field list and filter conditions in effect at the time of their execution; the command syntax permits additional FOR and WHILE conditions to be specified. These commands also allow a further selection of the fields to be used.

In "A Perspective on Data Models" (Clyde Holsapple, *PC Tech Journal*, July 1984, p. 113) the SQL example:

```
SELECT EMPNAME, EMPADDR, DEPNAME
  FROM EMPLOYEE, DEPARTMENT
  WHERE DEPID IN [7,12,3]
  AND DEPARTMENT.DEPID =
   EMPLOYEE.DEPID
  ORDER BY EMPNAME
```

was used to produce a dynamically sorted report of employee names, addresses, and department names for all employees in departments 7, 12, or 3. The same query can be accomplished in many ways in dBASE III PLUS. Two examples are presented below.

```
SELECT 2
USE DPARTMNT.DBF
INDEX ON DEPID TO DEPID.NDX
SET FIELDS TO DEPID, DEPNAME
SELECT 1
USE EMPLOYEE.DBF
INDEX ON EMPNAME TO EMPNAME.NDX
SET RELATION TO DEPID INTO
   DPARTMNT
SET FIELDS TO EMPNAME, EMPADDR
SET FILTER TO DEPID $ [7,12,3]
SET FIELDS ON
LIST EMPNAME, EMPADDR, DEPNAME
```

Assuming the index files on the department and employee data files are normally maintained as part of the application, the following commands could be entered as an alternative:

```
SELECT 2
USE DPARTMNT INDEX DEPID
SELECT 1
USE EMPLOYEE INDEX EMPNAME
SET RELATION TO DEPID INTO
   DPARTMNT
LIST EMPNAME, EMPADDR,
   DPARTMNT—>DEPNAME
   FOR DEPID $ [7,12,3]
```

Note that in each of these dBASE queries, all of the set-up prior to LIST could have been captured in a view and recalled with one command, SET VIEW TO EMPDEPT. This would be a common view into the employee and department files, and, once established, could be used for repeated commands to view, print, or print labels. The selection process could also continue by adding conditions such as state or zip code selection from the address field, and the resultant table could be copied to a new file for distribution.

When desired, commands such as COPY, JOIN, or TOTAL produce new tables with fields selected from the active field list and extracted from more than one related file. The ability to establish a relation of several files, select desired fields, establish filter conditions, and then copy or join portions of this virtual table to create a new table provides efficiency, flexibility, and power in the query process, but does not fully automate the process as is done in an SQL-type query language.

IMPORT/EXPORT

dBASE III PLUS can import data from Multiplan SYLK and Lotus 1-2-3 .WKS spreadsheets, general DIF files, column-positioned ASCII files such as those produced by most spreadsheet or word processing programs, or delimited ASCII files. The delimiter may be specified. The command APPEND FROM is used to import data from these files by specifying the file type. The COPY TO command is used to export data from a dBASE data file into one of the above formats by specifying the file type in the command. As discussed above, the COPY command can also select fields and impose conditions for the set of data to be copied.

The IMPORT and EXPORT commands provide an interface with the PFS files from Software Publishing Corporation. The PFS screen layout definition is captured automatically into a dBASE format file for use with the imported data file and is created in PFS form from a dBASE format file when exporting. A view file is also created when importing, and the command SET VIEW TO <PFS file name> opens the file with its format screen.

The ?/?? <expression list> command can be used to prepare files of nearly any format for output. An alternate file may be specified with the SET ALTERNATE TO <filename> command, and output can be toggled on and off with the SET ALTERNATE ON/OFF command. The output of the ?/?? commands is sent to the alternate file as well as optionally to the screen or printer. The file is considered to be an output string of bytes, and any character except a byte of eight binary zeros may be sent with the CHR(*n*) function.

The applications generator program, supplied in encrypted and linked form as discussed above, is the only real application provided with dBASE III PLUS. The applications provided with the tutorial material—a checkbook program and a travel reservations program—may have some value to specific users, and the source code is provided for examination and modification.

Hundreds, if not thousands, of applications are written in dBASE II or III and sold by third-party vendors. Many of these applications are certain to be

rewritten or converted to dBASE III PLUS. Ashton-Tate is planning to publish a catalog of third-party applications.

dBASE CTOOLS, supplied by Ashton-Tate, provides a library of functions written in the C language and a standard interface module. This module provides a path between dBASE program files and an external library of functions. The CTOOLS series is designed to enhance performance of memory-intensive calculations and array manipulation and to provide facilities for development of special purpose applications. Ashton-Tate intends to release additional library functions for the CTOOLS program in the future.

SAMPLE APPLICATION

The development of *PC Tech Journal's* sample application of a database of three files to track articles and authors revealed several strengths and weaknesses in dBASE III PLUS. Some of these have already been mentioned in the sections discussing the individual features of the program. Choices in the way the package uses and relates files showed their impact on the design of database, program, and user interface.

One of the stumbling blocks mentioned earlier was the inability of dBASE to relate one file into more than one other at the same time. If the sample application were to be redesigned, the one specific piece of unique data carried by the Issue file, the deadline date, could be included in the Article file, accepting the redundancy of having the date repeated in each article record. The deadline date for an issue should not change often, and a single command to replace it with a new date throughout the file would be a small price to pay for the associated reduction of programming effort in the article data entry and other programs.

Another problem area was the layout of the sample article data entry screen. The inaccessibility of data entered by the user on a field-by-field basis during full-screen operations until the execution of the READ command required substantial program logic for the look-up of the data from the Author data file. The reason for this is that the user may change the key (author name) used to relate the Article to the Author file while entering the article data. This ability was desired in order to permit the user to change the author name being entered if incorrect data were retrieved from the related author record. In real applications, this arises frequently when a data entry screen uses a client or account number to retrieve

TABLE 1: *Benchmark Results*

BENCHMARK TASK	TIME (secs)
Add 900 records to an empty database table	45
Index table on two fields (7 bytes)	14
Document and tally codes from one column	49
Mass change of one column (28 rows of 900)	5
Extract selected records to create a text file	2

dBASE III PLUS performed extremely well in all tests except the third, where it placed at about the median position compared to programs previously reviewed.

data from another file. The usual practice is to restrict the data entry process from going beyond the field used for look-up until the retrieved data are accepted. This procedure is fine, except that the simple format file approach provided by dBASE cannot be used.

The production of labels for authors and coauthors having articles in an issue was another procedure demanding some effort. In this case, however, the fault lies more with the relational model than with dBASE. The labels were supposed to be created in one pass through the section of the Article database containing articles for the specified issue. The sample application design allowed for two names (author and coauthor) in the Article file for each article. The elegant label printing feature works well with related files, retrieving data from any of the files, but the author and the coauthor could not both be pointed into the Author file at the same time. The Author file could have been used to print the labels, making it the master file, but this would require the Article file to be indexed on both authors and coauthors simultaneously, an option not available in many database managers.

The sample application database design limits the number of authors for an article to two, which is a compromise between the maximum number of authors anticipated per article and storage space used by the Article file. The only real solution to this problem in a relational model is to provide an intermediate file of records containing both article and author keys. This file establishes the many-to-many relationship needed to handle the fact that an article may have several authors, and authors may write several articles, but also raises several implementation questions. Which file is used as the master in the relationship, and how is the relationship between articles and authors established? This operation cannot be implemented without programming loops or using file joins.

The reports required by the sample application provided a test of the report generator. One report called for fairly sophisticated layout of articles by issue with section subtotals, totals of edit page count and listing page count, grand totals, and section headers identifying issue and volume number. Page headers and footers were to include the page number, title, time, and date. The report writer was able to handle every requirement except the one for footers.

The technique used to specify printing the issue volume and number in the section header is not obvious from the documentation; previous similar experience with dBASE III led to its discovery. The exact report requirements were also programmed using the @ row,col ... SAY command and memory variables to count lines and pages and to compare for breakpoints. The logic for programming reports is no more complex than it would be in any other structured language.

The vast flexibility of methods and techniques for retrieval of data made short work of the ad hoc queries required by the sample application. In most cases, data could be retrieved in at least two ways, one requiring only a single command. For example, the query to determine the number of editorial, listing, and total pages in an issue could be produced by the command:

```
SUM ALL EDIT_PAGES, LIST_PAGES,
   EDIT_PAGES + LIST_PAGES
   FOR VOLUME = "3"
   .AND. NUMBER = " 7"
```

This requires dBASE to read all records in the Article file.

An alternative that takes advantage of the index's ability to put the Article file into issue volume and number sequence is to position to the first article in the issue, then do the sum until the issue number changes, as follows:

```
SEEK "3 7"
SUM EDIT_PAGES, LIST_PAGES,
   EDIT_PAGES + LIST_PAGES
   WHILE NUMBER = " 7"
```

The ability to use fields from related data files in the FOR or WHILE conditions also made the retrieval of articles received after deadline a simple matter of comparing the receive date in the Article file to the deadline date in the linked Issue file. Again, a single command or the seek-and-process-while technique could be used, as shown in the following examples:

```
DISPLAY OFF ALL TITLE, DATE_RECD
   FOR VOLUME="3"
   .AND. NUMBER=" 7"
   .AND. DATE_RECD > ISSUE->
      DEADLINE
```

or:

```
SEEK "3 7"
DISPLAY OFF TITLE, DATE_RECD
   FOR DATE_RECD > ISSUE->
      DEADLINE
   WHILE NUMBER=" 7"
```

The sample application was a good test of many of the features of dBASE III PLUS, but certainly not beyond any of its capabilities or capacities. If the application were redesigned with dBASE III PLUS in mind from the start, it could be easily implemented using many of the user interface features provided by the package to replace much, but not all, of the custom programming.

BENCHMARKS

The same five benchmarks were run on dBASE III PLUS that are run for all data managers reviewed in this series—in the same controlled PC/AT machine configuration. The results are shown in table 1. The program performed extremely well in all tests except the third, where it placed at about the median position compared to programs previously reviewed.

When several ways existed to implement a benchmark, the method appearing to be most efficient was used. The appending and indexing operations of the first two tests were straightforward, using the APPEND FROM and INDEX ON commands.

The index file created on the combined state and zip code fields in benchmark 2 placed the file in state sequence; this was applied in benchmark 3, listing and counting the occurrences of unique state codes. A subtle trade-off is inherent in this test. The fact that the index formula contains an extra five bytes for the zip code makes the index file substantially larger than it would be if only the two-character state code were indexed. This imposes a penalty on retrieval via the index, because less of the index file can be buffered in the DOS buffers. The trade-off is the time needed to create the index on the state field alone. In tests run using a large RAM disk in a Compaq, both approaches were within one second (just over one percent) of each other. On a hard disk in the same computer, they were about two percent apart. If the state-only index file were in existence for other reasons, the 41 seconds for benchmark 3 could have been reduced by several seconds.

Another factor affecting this test is that it displays information to the screen. The screen management functions in dBASE are not as fast as in other packages, and the ? print statement below slows down the loop.

```
DO WHILE .NOT. EOF()
   MSTATE=STATE
   COUNT REST TO STATECOUNT
   WHILE STATE=MSTATE
   ? MSTATE, STATECOUNT
ENDDO
```

The fourth test, replacing the 28 occurrences of the state code CO with CL, was tried three different ways—one of which illustrates a hidden, but logical, restriction of dBASE. The most straightforward but slowest method is to use the command REPLACE ALL STATE WITH 'CL' FOR STATE='CO' on the unindexed file. This causes dBASE to read all records in the data file and upsets the synchronization of the associated index file. One approach that often confuses dBASE programmers is to use the index file to seek to the first occurrence of state CO and then perform the replacement while the state is still CO, thus limiting the amount of records to be read. The problem is that the first replacement of the state field with a new value moves the record's logical position in the file, as determined by the index. The current record now contains the value CL, which does not equal CO, so the replacement process stops before all occurrences are found. The third and fastest method is to use a loop that will seek and replace until all replacements have been accomplished, signified by the return of an end-of-file condition from the seek. The code is as follows:

```
DO WHILE .T.
   SEEK "CO"
   IF EOF()
      EXIT
   ENDIF
   REPLACE STATE WITH "CL"
ENDDO
```

The fifth benchmark uses the seek-and-process-while approach, taking

advantage of the existing state/zip index. The commands are:

```
SEEK "CA"
COPY REST TO CAUTHOR
  WHILE STATE="CA" DELIMITED
```

Because the state field is not changed by the COPY command, the WHILE clause stops the copy as soon as the last CA record is processed.

EVOLUTIONARY ADVANCEMENT

Ashton-Tate has succeeded in producing a substantial, but evolutionary advancement to the dBASE product line. Users familiar with dBASE III will enjoy the increased performance and enhanced features in dBASE III PLUS, and developers of custom applications will appreciate much of the new user interface. dBASE III PLUS handles a wide variety of applications, but the lack of a compiler may adversely affect the performance in large, multiuser systems.

The attributes of a relational database manager are present in dBASE III PLUS, but substantial user understanding of data relationships and the relational model is required before useful multifile relational databases can be constructed and implemented. The indexing, filtering, and command syntax features provide substantial power to manipulate and manage data; many ad hoc operations that are cumbersome in dBASE III and other programs are simple in dBASE III PLUS. The assistant interface captures a significant portion of this power in the interactive mode, and its system of pull-down menus and pop-up field and file lists is easy and powerful.

Developers can produce applications quickly and easily if the user interface features are employed. Otherwise, all communications between the applications program and the user must be tediously coded at a low level in the dBASE language. dBASE III PLUS provides automatic record locking for multiuser applications in which the default user interface is applied, but any sophisticated screen handling requires programming of the file and record locking. Very few, if any, multiuser applications can be implemented without programming the locking functions.

Two significant drawbacks to the dBASE III PLUS database structure are the inability to relate one file directly into more than one other file and the limit of 20 simultaneous open files, including those reserved by DOS. The development of complex applications in dBASE III PLUS requires attention to detail in the design of the data files, index formulas, and relationship structure.

The performance of dBASE III PLUS in multiuser network applications is yet to be determined. Several factors will influence its effectiveness in the LAN environment. Whether the user interface is sufficiently flexible to support multiuser applications remains to be seen. The lack of a compiler requires careful attention to program efficiency, and memory variable manipulation speed has not displayed the spectacular increase enjoyed by the indexing operations. dBASE III PLUS has no significant movement of data processing operations from the LAN node to the server in multiuser operations, and several users with a few filtered, linked, and indexed files will place a substantial amount of traffic on the network.

This problem is not specific to dBASE; most multiuser data managers keep all of the intelligence at the node, employing the server simply as a traffic cop. What is needed is an intelligent database server program, designed to understand the user's database view as defined by the open data files, index files, relationship formulas, and filter conditions. This view would specify a *next* record, which may be several hundred away from the current position. If the server were to search out that next record before sending it to the node, much network traffic could be eliminated. The node processor could then do what it does best—manage the user interface to the data supplied by the server.

Techniques to improve performance may be explored in the area of locating some files at the local user node. Subprograms called within loops may be stored on a RAM disk or local hard disk to reduce the frequency of their retrieval over the network. When data files are used for reports and exclusive use is required, ad hoc index files can be created locally to reduce network traffic during both the index building and data retrieval processes.

The most important attributes of dBASE III PLUS may be the flexibility and power of the command language and the power of the index file formula. Almost any data manipulation problem can be solved in a variety of efficient ways. dBASE III PLUS is especially well suited to unusual applications requiring unique solutions.

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LISTING 1: AUTHLBL.PRG

```
*AUTHLBL.PRG - Program to print labels for all authors who have
*              articles in a given issue, suppressing duplicates.

* establish environment
SET TALK OFF            && don't echo status changes to screen
SET SAFETY OFF          && overwrite temp files, don't ask user if ok
SET PRINT OFF           && make sure printer is off
SET UNIQUE OFF          && index creation allows duplicate entries
MVOL=0                  && preset memory variables: volume and number
MNUM=0

DO WHILE .T.     && loop here if unknown issue or user wants to repeat
  CLEAR                 && clear screen, get volume, number from user
  @ 10,10 SAY "Enter Volume and Number for labels (0,0 to quit):"
  @ 12,20 SAY "Volume" GET MVOL PICTURE "9"
  @ 12,COL()+4 SAY "Number" GET MNUM PICTURE "99"
  READ                  && collect the data from the GETs

  IF MVOL+MNUM=0        && user entered zeros to quit
    EXIT
  ENDIF

  @ 15,10 SAY "Sorting the author names and culling duplicates."
  SELECT 1              && display comfort message; open article file
  USE ARTICLE INDEX ARTICLE           && index is volume and number
  SEEK STR(MVOL,1,0)+STR(MNUM,2,0)    && position to start of issue

  IF .NOT. FOUND()                    && no such issue, get another
    @ 15,10 SAY "Cannot find issue. Please reenter volume and number."
    WAIT                              && pause for read of message
    LOOP
  ENDIF

  *  Copy the primary author names to temp1.dbf  (this is very fast
  *  because the SEEK got us to first record immediately, and the
  *  COPY will stop as soon as the issue number changes.
  COPY TO TEMP1 REST FIELDS AUTHOR_LN, AUTHOR_FN WHILE MNUM=NUMBER
  SEEK STR(MVOL,1,0)+STR(MNUM,2,0)      && Position to start of issue

  *  Now get the coauthors (if any) to temp2.  Use delimited format
  *  so we can append names to temp1 without conflict in field names
  COPY TO TEMP2 REST FIELDS COAUTHORLN, COAUTHORFN WHILE MNUM=NUMBER ;
    FOR LEN(TRIM(COAUTHORLN+COAUTHORFN)) > 0 DELIMITED

  *  Get all the authors together by appending the coauthors to temp1.
  USE TEMP1                     &&  open temp1 in work area 1
  APPEND FROM TEMP2 DELIMITED   &&  add in the coauthors

  *  Create a unique index.  This will eliminate duplicate labels.
  INDEX ON UPPER(AUTHOR_LN+AUTHOR_FN) TO TEMP1 UNIQUE
  SELECT 2                   && open the author file in work area 2
  USE AUTHOR INDEX AUTHOR    && key is uppercase last+first name
  SELECT 1                   && set relationship into author file key
  SET RELATION TO UPPER(AUTHOR_LN+AUTHOR_FN) INTO AUTHOR

  * Now print the labels.  The parameter "SAMPLE" prints labels of
  * asterisks for alignment. The label generation form looks up
  * all data (author name and address) from the author file.  The
  * temp1 file of uppercase names simply selects and points to the
  * appropriate author record for the label. Label form contents are:
  *    Line 1:  author->AUTHOR_FN, author->AUTHOR_LN
  *    Line 2:  author->ADDRESS
  *    Line 3:  TRIM(author->CITY) + ",", author->STATE, author->ZIP
  * dBASE III PLUS automatically suppresses blank lines within a label
  * and formats to the number of lines on the specified label size.
  * A comma between fields on a label line causes dBASE to trim the
  * first field of trailing blanks and insert one blank between fields.
  * A sample label:
  *             John Brown
  *             3559 South 24 St.
  *             Stanleyford, IN 76828
  *
  LABEL FORM ARTLABEL SAMPLE TO PRINT

ENDDO   && back for another issue.
CLOSE DATA
RETURN
```

JON FORREST

Matching Regular Expressions

Regular expressions combine simple syntax and surprising expressive power.

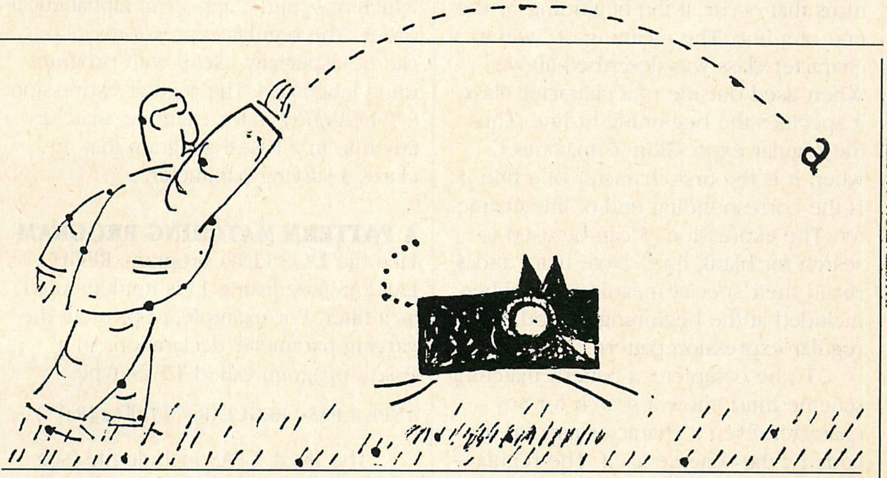

ILLUSTRATION • MACIEK ALBRECHT

The technique of regular expression pattern matching is considered quite useful in standard UNIX text handling programs, such as ED, LEX, and GREP. However, most DOS programs handle text processing using some ad hoc technique. The basic problem involved with text pattern matching is to detect and locate a particular substring within a given string. A simple example would be to find all occurrences of the word *title* within the string *call vprts (title, nc,ncall)*. Ad hoc techniques are adequate in an instance such as this. They also can be used for other simple operations, such as finding wild-card strings.

Consider, however, a more complicated situation involving pattern matching: searching a given text for the word *title* each time that it appears in lowercase letters and within parentheses. The programming task is manageable, but finding the desired pattern in any but the simplest of contexts would require a significant amount of work.

For complicated pattern matches, the regular expression syntax technique below is the answer. It is simple to program and can specify 99 percent of the strings a user might want to find. This implementation uses UNIX syntax. The listings that accompany the article are written in Turbo Pascal.

REGULAR EXPRESSIONS

A regular expression is a string of normal ASCII characters. It is used to search a text for every occurrence of a particular string. The simplest example of a regular expression is a single character; the regular expression *z* finds the string *z* wherever it occurs in the text being searched. Similarly, the regular expression *cat* finds the string *cat* wherever it occurs. Note that the regular expression *cat* is actually the concatenation of three smaller regular expressions: *c*, *a*, and *t*. Table 1 lists examples of regular expressions along with the meaning of each.

Because the DOS wild-card syntax for an unspecified character is *?*, the search pattern *?at* finds *cat*, *bat*, *hat*, and *fat*. The question mark cannot be used for this purpose in a regular expression; the period is used instead (*.at*). This search pattern matches not only the desired strings, but also any string within the text that contains a character followed by a lowercase *at*.

The case of a character is significant in regular expressions. The character class syntax, however, is available to perform case-insensitive searches. To specify a string that begins with *b* and ends with *at*, the class construct *[Bb]at* can be used. This finds both *Bat* and *bat*. Similarly, *[Pp][Hh][Dd]* matches PhD in any combination of upper- and lowercase characters.

The class syntax is useful in other situations. Because a character class is a set of characters, any one of which is accepted as a match, the class *[aeiou]* matches any lowercase vowel. A dash shorthand is available for sequential ranges of ASCII values. Thus, the regular expression *[a-z]at* matches *aat*, *bat*, *cat*, *dat*, and so on. The regular expression *NUM[0-3]* matches four strings: *NUM0*, *NUM1*, *NUM2*, and *NUM3*.

A useful extension to the character class is the negative character class—an expression that matches all characters except those included in the class. A negative character class is designated by a caret (^) inserted immediately following the left square bracket of the expression. For example, *[^AaBbCcDd]* matches all characters except the first four letters of the alphabet. The caret is not considered a member of the class. With the exception of ^ and –, all special characters are interpreted as literal characters when they are enclosed in square brackets.

One of the most powerful features of regular expressions is closure. A closure of a character can be used to pattern match zero or more occurrences of the specified character pattern. This feature is indicated by an asterisk (*) placed immediately after the designated character pattern. For example, *x** matches any successive occurrences of *x*, as well as the situation in which no occurrences of *x* are found. Similarly, *[0-9]** matches successive occurrences of numeric characters or the absence of any numeric characters.

Closure can be used, for example, by an author who writes a story in which the number of *o*s in the word *good* is increased to indicate a corresponding increase in the degree of pleasure, as in *good*, *goood*, and *gooood*. If the author later wants to change these words, he can use the reg-

ular expression pattern matching technique to speed the substitution process. The closure capability is useful here because the regular expression go*d matches all the various occurrences of *good* within the text. It even can find the word spelled without an *o* (*gd*).

A closure matches as many characters as it can find; the o* regular expression in the above example matches all five *o*s in *goooood*.

Two more special characters, the caret and the dollar sign, indicate patterns that occur at the beginning or the end of a line. The meaning of ^ within a character class was described above. When used outside of a character class, it specifies the beginning of line. Thus, the regular expression ^C matches *C* when it is the first character of a line. $ is the corresponding end-of-line character. The expression ^$ can be used to search for blank lines. Note that ^ and $ retain their special meaning only when included at the beginning or end of a regular expression pattern.

To be complete, a pattern matching scheme must allow a search for any character, even a character used as a code by the scheme itself. The regular expression syntax uses the slash to distinguish literal from special characters. For example, an asterisk can be specified for a search by preceding it with a slash.(The expression // specifies the slash character itself.)

The features described here do not constitute a full implementation of regular expression pattern matching. Nonetheless, they allow the user to perform a great variety of searches. The sequence (.*) can be used to find characters enclosed in parentheses; zzzz* matches three or more lowercase *z*s; a[^a]*b[^b]*c[^c]* matches any line in which *a*, *b*, and *c* appear in alphabetical order. The regular expression syntax can be especially useful with programming languages. The regular expression (.*[Vv][Aa][Rr].*), for example, matches any line in a Pascal program that declares a varying parameter.

A PATTERN MATCHING PROGRAM

Like the DOS FIND program, REGULAR.PAS (see listing 1) is implemented as a filter. For example, to print all the varying parameter declarations in a Pascal program called T.PAS, type:

```
TYPE T.PAS | REGULAR (.*[Vv][Aa][Rr].*)
```

The INOUT.PAS include file (see listing 2) contains the piped I/O procedures of the program. Taken from ADDREC.PAS (see "Filters and Finite Machines," Larry W. Loen, February 1986, p. 181), these procedures access the DOS functions 3FH and 40H. Piped I/O allows multiple filter invocations on a single input stream. The command

```
TYPE T.PAS | REGULAR (.*[Vv][Aa][Rr].*) |
  REGULAR count
```

(which must be typed on a single line) selects all lines that declare a varying parameter and contain the lowercase variable name *count*. However, piped I/O has a disadvantage: regular expressions cannot contain the characters <, >, or | because DOS interprets them as piping or redirection commands.

REGULAR.PAS is based on the text matching program described in Kernighan and Plauger's book, *Software Tools in Pascal* (Addison-Wesley, 1981). Because of the complexity of the pattern matching problem, Kernighan and Plauger break the program into two parts. First, a regular expression is converted into a convenient internal form. Next, the internal form is matched against the input line. If a regular expression is considered a program, part 1 compiles it into pseudocode, and part 2 interprets the pseudocode.

The encoding step is performed by the routines in COMPILE.PAS (see listing 3). MAKEPAT, along with its subsidiary routines, constructs the internal representation; it loops through the characters of the input string (named ARG in listing 3) inserting the necessary characters into the encoded string (named PAT in listing 3). Table 2 lists several regular expressions and the encoded form of each.

The character LITCHAR (indicated by the at sign) is used in the internal form to distinguish between characters that have special meaning in regular expressions, such as ., [, and *, and standard characters, such as *a* and *4*. The internal form of *a* is *@a*. In the string PAT in listing 3, * specifies the closure operator, and @* is used to specify the asterisk itself.

Character class syntax is changed only slightly in the encoding process. The class [abc] becomes [3abc when converted to internal form. The *3* in this example is not the ASCII value for 3, but the hex value. It indicates the number of characters in the class.

Negative character classes are transformed in a similar manner, but the prefix character is the excalmation point. For example, the regular expression meaning *any character but a, b, or c* is typed [^abc] and encoded !3abc.

TABLE 1: *Search Patterns*

EXPRESSION	EXAMPLE MATCHES
a	any lowercase *a*
.at	Bat, bat, cat
[Bb]at	Bat or bat
[aeiou]	any lowercase vowel
[^a]	any character except *a*
[a-z]	any lowercase letter
go*d	gooood, good, god, gd
^c	lowercase *c* at beginning of line
c$	lowercase *c* at end of line

Like DOS wild cards, regular expressions are search specifiers. However, in regular expressions, case is significant, and the asterisk indicates the procedure called closure.

TABLE 2: *Representing a Pattern*

EXPRESSION	INTERNAL REPRESENTATION
a	LITCHAR a
.	ANY
\\.	LITCHAR .
[Bb]at	CCL 2 B b LITCHAR a LITCHAR t
[aeiou]	CCL 5 a e i o u
[^a]	NCCL 1 a
[a-g]	CCL 7 a b c d e f g
go*d	LITCHAR g * LITCHAR o LITCHAR d
^c	BOL LITCHAR c
c$	LITCHAR c EOL

Regular expressions are preprocessed to simplify the matching algorithm. The internal forms are strings of literal characters as well as special characters defined in REGULAR.PAS.

The function DODASH expands range specifications, such as *a-k* to the equivalent expression, in this case *abcdefghijk*.

The period, dollar sign, and caret outside of a class are transferred to the internal form of the expression without any change in form. The closure character, however, is moved in front of the character it alters—*x** becomes **@x*.

FINDING A MATCH

To match a line with a compiled regular expression, the line is checked against the string PAT, one character at a time. This process is carried out by the function MATCH. Matching the pattern to a substring at a specific offset in the line is performed by AMATCH.

Two complications can arise during the pattern-matching process. First, a character in the line might not match exactly one character in the pattern. For example, the pattern . matches a string comprised of a single character, but so do *@a* and *[5abcde*. The function PAT_ADVANCE updates the pattern index appropriately, depending on the size of the pattern. The function LIN_ADVANCE also helps to keep the pattern index in step with the input line index, accounting for the position specifiers (^ and $), which do not increment the line index at all.

Closure causes a major complication when writing REGULAR.PAS. A closure can match any number of characters, including zero; the exact number of matches depends on the rest of the pattern and of the input string. Suppose the closure is *x**, and the string is *xxxx*. If *x** represents the entire pattern, it should match all four *x*s. However, if the full pattern is *x*x*, the closure should match the first three *x*s and leave the last *x* in the line to match the last *x* in the pattern.

The function MATCH_CLOSURE deals with this problem of closure. As explained above, a closure matches as many characters as are possible. MATCH_CLOSURE determines the maximum number of possible matches and saves that value in the integer variable *n*. It then calls AMATCH recursively to match the rest of the pattern against the rest of the line. If the remainder of the pattern and the remainder of the line match, the closure length is correct, and MATCH_CLOSURE is finished. Otherwise, the closure length is shortened by one, and AMATCH is called again. This process continues until the whole line matches or until a match fails because of closure length zero.

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LISTING 1: REGULAR.PAS

```
PROGRAM regular;
{
   Search input lines for regular expressions.  Similar to DOS
   "FIND.EXE" and UNIX "GREP".  Reads from standard input, writes
   to standard output.  Usage: C:>DIR | REGULAR PAS
}

CONST
   {                    REGULAR EXPRESSION OPERATORS                }
   CLOSURE = '*';
   BOL = '^';             { match starting at beginning of line      }
   EOL = '$';             { match at end of line                     }
   ANY = '.';             { match any single character               }
   CCL = '[';             { begin character class                    }
   CCLEND = ']';          { end character class                      }
   NEGATE = '^';          { signify negative character class         }
   NCCL = '!';            { negative character class: internal form  }
   LITCHAR = '@';         { next character not an operator           }
   ESCAPE = '\';          { treat next operator as literal character }
   DASH = '-';            { consecutive range within class           }

   EOF_NUM=255;  { end of file }
   EOLN1_NUM=13; { return }
   EOLN2_NUM=10; { line feed }
   ENDSTR = ^A;  { End String: internal code for end of line      }



{$I InOut.pas} { Get line from Standard Input, Put line to STDOUT }

var ARG,            { input string: regular expression  }
    LIN,            { line from standard input          }
    PAT: maxstr;    { regular expression (internal form)}

{$I Compile.pas}    { compile regular expression to internal form }

function locate(c: char; pat: maxstr; offset: integer) : boolean;
{
   Search for the character C in the character class at pat[offset]
}
var i: integer;
begin
    { size of class is at pat[offset], characters follow }
    locate:=true;
    i:=offset+ord(pat[offset]);  {last position in class}
    while i>offset do
      if c=pat[i] then exit else i:=i-1;
    locate:=false;
end;

function lin_advance(lin: maxstr; l: integer;
                            pat: maxstr; p: integer): integer;

{
   Matches character pattern pat[p] against input line characters
   starting at lin[l].  LIN_ADVANCE=-1 means no match.
}

begin
  lin_advance:=-1;
  case pat[p] of
           LITCHAR: if lin[l]=pat[p+1] then lin_advance:=1;
               BOL: if l=1 then lin_advance:=0;
               ANY: if l<length(lin) then lin_advance:=1;
               EOL: if l=length(lin) then lin_advance:=0;
               CCL: if locate(lin[l], pat, p+1)
                             then lin_advance:=1;
              NCCL: if (l<length(lin)) and
                       (not (locate(lin[l], pat, p+1)))
                          then lin_advance:=1;
             else error('in lin_advance: can''t happen')
          end; {case}
end;

function pat_advance(pat: maxstr; p: integer) : integer;
```

```
{
  Returns offset of next pattern within PAT string.  Current pattern
  starts at PAT[P].  ex.  if pat="@c@a@t" and p=1 then pat_advance=3.
}
begin
   case pat[p] of
      LITCHAR: pat_advance:=p+2;
      BOL,EOL,ANY: pat_advance:=p+1;
      CCL,NCCL: pat_advance:=p+ord(pat[p+1])+2;
      CLOSURE: pat_advance:=p+1;
         else error('in pat_advance: can''t happen');
    end; {case}
end;

function amatch (lin: maxstr; offset: integer;
                 pat: maxstr; p: integer): boolean; forward;

function match_closure(lin: maxstr; offset:integer;
                           pat:maxstr; p:integer): integer;
{
   Match as many characters as possible with closure.
   Does rest of pattern match remaining characters on line?
   If not, shorted closure match by one and try again.
   If closure shortened to 0, no match is possible (match_closure=-1)
}
var n, backtrack, increment: integer;
begin
  match_closure:=0;
  n:=offset;
  repeat
      increment:=lin_advance(lin,n,pat,p);
      if increment>=0 then n:=n+increment;
  until ((increment<0) or (n>length(lin)));
  if n=offset then exit;              { closure length is zero }
  for backtrack:=n downto offset do
      begin
           if amatch(lin,backtrack,pat,pat_advance(pat,p)) then
              begin
                 match_closure:=backtrack;
                 exit;
              end;
      end;
  match_closure:=-1;
end;

function amatch;
{
   Anchored match.  Does pattern PAT match input line starting at
   LIN[offset]?  Loop through PAT distinguishing the two cases;
   if PAT[P] is a closure, find appropriate closure size to match.
   Otherwise, just compare characters and update PAT and LIN indexes.
}
var l,increment, closure_end: integer;

begin
     amatch:=false;
     l:=offset;
     while (p<=length(pat)) do
        begin
          if l>length(lin) then exit;
          if pat[p]=CLOSURE then
           begin
             closure_end:=match_closure(lin,l,
                        pat,pat_advance(pat,p));  { jump over "*" }
            if closure_end<0 then exit;
            l:=closure_end;
            p:=pat_advance(pat,p);
          end
           else
              begin
                increment:=lin_advance(lin,l,pat,p);
                if increment<0 then exit;
                l:=l+increment;
              end;
          p:=pat_advance(pat,p);
        end; {while}
     amatch:=true;
end;
```

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```
function match(lin,pat: maxstr): boolean;
{
   Loop through input line checking for match at each position.
}
var i: integer;
begin
  match:=true;
  for i:=1 to length(lin) do if amatch(lin,i,pat,1) then exit;
  match:=false;
end;

begin
 if not getarg(arg) then error('no pattern specified');
 pat:=makepat(arg);
 while getline(lin) do
        if match(lin,pat) then putline(lin);
end.
```

LISTING 2: COMPILE.PAS

```
{ Input and Output procedures follow.  Interface to standard I/O included. }

TYPE
     regpack = record    { used for Standard I/O DOS calls }
                     ax,bx,cx,dx,bp,si,di,ds,es,flg : integer
                end ;
     ary = byte;
     xpt = record
                case integer of
                      1: (ptx : ^ary) ;
                      2: (qq,rr :integer)
                   end;
     maxstr = string[255];
VAR
 register : regpack;
 xx : ary;
 here : xpt;
 b: byte;

procedure putstdout(wr: byte);

{  Procedure to put the next byte of Standard Output out to
   MS DOS 2.x Standard Output file. }

    begin
      here.ptx := addr(xx);
      xx  := wr;
      register.ds := here.rr;
      register.dx := here.qq;
      register.cx := 1;
      register.bx := 1;
      register.ax := $4000;
      intr($21,register);
    end;

procedure getstdin(var ip: byte);
{
    Procedure to get next byte of input from DOS 2.0, 2.1
    Standard Input file.  This filter uses only ascii characters
    (maximum decimal value 127) so 255 was chosen as the
    end-of-input flag.
}
begin
     here.ptx := addr(xx);
     register.ds := here.rr;
     register.dx := here.qq;
     register.cx := 1;
     register.bx := 0;
     register.ax := $3F00;
     intr($21,register);
     if register.ax = 0 then ip:= 255;
     if register.ax <>0 then ip:= xx;
end;

function getline(var lin: maxstr): boolean;
{
```

```
   Reads a line from the Standard Input file and loads it
   into the string LIN.  The end of line identifier ENDSTR
   is appended to each line.  Unprintable characters are
   ignored.
}
begin
   getline:=false;
   lin:='';
   repeat
      getstdin(b);
      case b of
            32..125: if length(lin)<254 then lin:=lin+chr(b);
            eof_num: exit;
         end; {case}
   until b=eoln1_num;
   lin:=lin+ENDSTR;
   getline:=true;
end;

procedure putline(lin: maxstr);
{
   Feeds a line to Standard Output byte by byte, adding
   <carrage return> <line feed> at the end.
}
var i: integer;
begin
     i:=1;
     while lin[i]<>ENDSTR do
       begin
          putstdout( ord(lin[i]) );
          i:=i+1;
       end;
     putstdout(eoln1_num);
     putstdout(eoln2_num);
end;
function getarg(var arg: maxstr) : boolean;
{
   Command line parameters are returned in string ARG.
   Spaces within the Regular Expression pattern are
   preserved, but the Turbo parameter functions ignore
   leading and trailing spaces.
}
var i, arg_num: integer;
begin
  getarg:=false;  arg:='';  arg_num:=paramcount;
  if arg_num=0 then exit
      else
        for i:=1 to arg_num do
          begin
            arg:=arg+paramstr(i);
            if (arg_num>1) and (i<arg_num) then arg:=arg+' ';
          end;
  getarg:=true;
end;
```

LISTING 3: INOUT.PAS

```
procedure error(message: maxstr);
begin
  writeln('error in regular.com: ',message);
  halt;          { stop the program }
end;

function dodash(var expand: maxstr) : boolean;
{
   Expand character class like "a-h" to "abcdefgh".
   If syntax is wrong, DODASH returns false and all subsequent DASH
   operators are interpreted as literal characters.
}
var st: maxstr; count: integer;
begin
  dodash:=false;
  st:='';
```

```
  if expand[1]>='0' then
    if expand[3]<='z' then
       if expand[1]<expand[3] then
         begin
           for count:=ord(expand[1]) to ord(expand[3]) do st:=st+chr(count);
           expand:=st;
           dodash:=true;
         end;
end;

function getccl(class: maxstr) : maxstr;
{
   Convert character class to internal form by removing brackets and
   expanding all DASH operators.  The internal form is
   <prefix character> <n> <char 1> <char 2> ... <char n> where prefix is
   CCL for positive character class and NCCL for negative character class.
}
var encoded, part1, part2, expand: maxstr; PREFIX: char; dash_spot: integer;
begin
   encoded:=copy(class,2,length(class)-2);  {drop CCL and CCLEND}
   if encoded[1]=NEGATE then
      begin
         PREFIX:=NCCL;  delete(encoded,1,1);
      end
         else PREFIX:=CCL;

   dash_spot:=pos(DASH,encoded);
  if dash_spot<length(encoded) then
   while dash_spot>1 do
     begin
        part1:=copy(encoded,1,dash_spot-2);
        part2:=copy(encoded,dash_spot+2,length(encoded));
        expand:=copy(encoded,dash_spot-1,dash_spot+1);
        if dodash(expand) then
          begin
             if length(part1)+length(part2)+length(expand)>255
                        then error('regular expression too complex');
             encoded:=part1+expand+part2;
             dash_spot:=pos(DASH,encoded);
          end
             else dash_spot:=0; { DASH syntax wrong. Terminate loop }
      end; {while}
   getccl:=PREFIX+chr(length(encoded))+encoded;
end;

function nextpat(var arg, pattern: maxstr) : boolean;
(*
  Delete next pattern from input string ARG and return it in PATTERN.
  ' '..'}' is the set of all literal characters.
*)
var class_length: integer;
begin
   nextpat:=false;
   if arg='' then exit;
   case arg[1] of
            ESCAPE: begin
                        if length(arg)=1 then arg:=arg+ESCAPE;
                        pattern:=copy(arg,1,2);
                        delete(arg,1,2);
                      end;
              CCL: begin
                      pattern:='';
                      class_length:=pos(CCLEND,arg);
                      if class_length<3 then
                        begin
                           pattern:=ESCAPE;
                           class_length:=1;
                        end;
                      pattern:=pattern+copy(arg,1,class_length);
                      delete(arg,1,class_length);
                     end;
      ANY,BOL,EOL, CLOSURE, ' '..'}':
                  begin
                    pattern:=arg[1];
                    delete(arg,1,1);
                  end
              else error('nextpat');
         end; {case}
     nextpat:=true;
 end;
```

```
procedure literal(var pat: maxstr; ch: char);
{ Internal format for a literal character.  ex. "C" --> "@C" }
begin
  pat:=pat+LITCHAR+ch;
end;

function makepat(entered_arg: maxstr): maxstr;
{

  Takes input parameter ENTERED_ARG and returns internal form. To
  encode a closure, the CLOSURE character must be inserted before
  the last pattern in the PAT string.  The starting position of the
  last pattern is held in OLD_LENGTH.
}
var pat, arg, pattern: maxstr; old_length, new_length: integer;
begin
   pat:='';  arg:=entered_arg;  old_length:=0;  new_length:=0;
   while nextpat(arg,pattern) do
    begin
      case pattern[1] of
     ESCAPE: pat:=pat+LITCHAR+pattern[2];
        ANY: pat:=pat+ANY;
        BOL: if pat='' then pat:=BOL else literal(pat,BOL);
        EOL: if arg='' then pat:=pat+EOL else literal(pat,EOL);
        CCL: pat:=pat+getccl(pattern);
    CLOSURE: if new_length=0 then literal(pat,CLOSURE)
                  else
                   insert(CLOSURE,pat,old_length+1);
           else literal(pat,pattern);
         end; {case}
       old_length:=new_length;
       new_length:=length(pat);
     end; {while}
     makepat:=pat;
end;
```

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CIRCLE NO. 196 ON READER SERVICE CARD

Reviews and Updates

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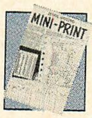

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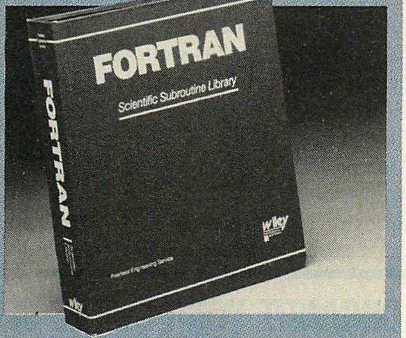

CIRCLE 362 ON READER SERVICE CARD

The FORTRAN Scientific Subroutine Library, introduced by Wiley Professional Software, is designed for programmers using FORTRAN to develop applications in the areas of science, engineering, or advanced statistics. The package includes more than 100 different technical subroutines, which are divided into 17 major categories.

The algebraic functions in the library include real matrix operations (transposition, row and column operations, vector inner products, traces, matrix multiplication, and eigen values and vectors); operations on matrices with complex elements (trace, multiplication, and other arithmetic operations); polynomial operations (evaluation, addition, multiplication, division, greatest common factor, and partial fractions); interpolation using three different methods; and polynomial differentiation. Numerical analysis can be performed with numerical integration using five different methods; the solution of equations using eight different methods; systems of equations (matrix inversion, the solution of simultaneous equations, determinants); numerical simulation of differential equations (four first-order, four second-order, and four third-order methods); function evaluation with complex arithmetic (square roots, *n*th roots, powers, sines, cosines, exponentials, logarithms, gamma functions, the Bessel J function, and the Legendre function); and numerical analysis (generation of Chebyshev polynomials and Fourier analysis).

The statistical functions offered include general statistics; probability (including negative binomial, and hypergeometric distributions); linear regression (simple and multiple); analysis of variance (seven different methods); and time series analysis (moving averages, autocovariance, cross covariance, seasonal indices, and exponential smoothing). The final category of functions deals with utilities and graphics.

To execute properly, the routines require a PC running DOS 2.0 or later, at least 128KB of memory, and a FORTRAN compiler.

The library routines were all tested on a PC/XT with 256KB of RAM. The machine was not equipped with an 8087 coprocessor chip. However, for most applications, installation of the 8087 is recommended. Because the software is not copy protected, no problems were encountered when transferring the library to the hard disk.

The performance of the subroutines was more than adequate. A multiple regression with 7 variables and 101 observations was completed in seconds, and a 10-by-10 matrix was inverted in a short time. However, when inversion was attempted with a 100-by-100 matrix, an overflow resulted.

The Scientific Subroutine Library package includes three disks and a manual. The first disk contains the complete library compiles in a FORTRAN .LIB file. Because this file consumes more than 200KB of memory, users may want to work with the individual routine modules provided in source code on the third disk. The second disk contains sample programs, one per module. The manual contains complete listings of the library and the sample programs, as well as a description of the parameters of each subroutine. This is helpful because the program listings include few comments. The manual and the sample programs are readable but cannot be thoroughly understood unless the user has experience with FORTRAN library routines. Telephone support is available to registered owners.

—TONY LIMA

QISORT

Quantumn Information Systems, Inc.
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Seattle, WA 98117
206/789-2888

PRICE: $175

CIRCLE 363 ON READER SERVICE CARD

One of the advantages of Ryan-McFarland COBOL (RMCOBOL) (see "Cobol Performs," Ted Mirecki, June 1985, p. 58) is that many third-party utilities are available to enhance the rather limited language capabilities of the Ryan-McFarland compiler. QISORT is one of these utilities. In addition to sorting data files produced by RMCOBOL, QISORT allows the user to perform rec-

ord selection and to write a file with a record layout different from that used in the input. It does not, however, perform merges.

This product can be used as a stand-alone utility executed from the DOS prompt or as a subprogram linked into the RM runtime system and called from within an RMCOBOL program.

When invoked from DOS, the program is controlled by a command line that specifies the sort parameters. These parameters are of three types. Only the first, which is the sort control parameter, is required. It specifies which fields are to be sorted, which values the fields contain, and whether the sort is ascending or descending. Up to 32 sort fields can be specified. The second parameter group specifies record selection criteria. It is limited, however, to determining whether the field is equal or not equal to some constant; other comparison operators or a comparison value read from the input file cannot be used. Up to 32 conditions can be strung together using AND and OR logic. The final input parameter specifies which fields of the input record are to be written to the output file.

These input parameters allow the user to control the sorting process. Because no relationship is required between the three sets of fields, selection is not restricted to sort fields, and neither selection nor sort fields must be written to the output.

Unlike files produced by some data managers, COBOL files do not include information about the field names, lengths, or types. This information must be in the command line, and preparing control input is tedious. Manually counting bytes and retyping lines are error-prone processes.

QISORT accepts as input any of the file types handled by RMCOBOL, including line sequential (variable length records terminated by CR/LF), variable-length binary sequential, fixed-length binary (processed within COBOL as either sequential or relative files), single-file indexed (data and indexes in the same file), and double-file indexed (data and indexes in separate files). For line-sequential and variable-length binary files, the output file is the same type as the input if the entire record is written. If field selection is in effect, or if one of the other file types is being used, the output is fixed-length binary. When sorting indexed files, QISORT extracts only the data portion and produces sequential output.

As mentioned above, QISORT can be incorporated into the RMCOBOL runtime system then called from within a COBOL program. A small interface module (provided with QISORT) must be linked into the runtime system using the linker supplied by Ryan-McFarland. At runtime, a COBOL CALL statement invokes this module which then loads the main QISORT program.

The three-part command structure of QISORT is almost as powerful as a built-in sort capability using input and output procedures. However, QISORT is not an adequate substitution for the SORT verb provided by high-level implementations of COBOL. In a true internal sort, the compiler keeps track of field positions, types, and lengths by name. With QISORT, the programmer performs these operations manually.

Another disadvantage is that QISORT displays its logo and progress messages while in use. This can disrupt a carefully laid out screen.

QISORT performs well. When executing the sort benchmarks used in previous reviews of high-level compilers (see "Cobol Performs, Part II," Ted Mirecki, July 1985, p. 111 and Part III, August 1985, p. 107), QISORT turned in times of 16 seconds for 100 records and

109 seconds for 300 records. This places it behind mbpCOBOL (with times of 8 and 63 seconds for 100 and 300 records, respectively) and ahead of Microsoft COBOL (29 and 119 seconds).

Documentation for QISORT consists of 28 typewritten pages that cover all aspects of the program's operation. The program is not copy protected.

QISORT does what it says it will do: it provides a sort and selection capability for RMCOBOL files. Despite the necessity for manual control input and the disruption of the screen, this product is a good bet for RMCOBOL users.

—TED MIRECKI

MINI-PRINT

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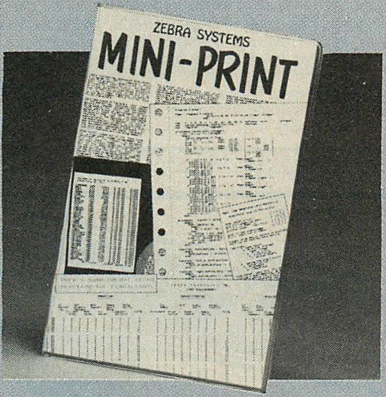

CIRCLE 364 ON READER SERVICE CARD

Zebra Systems has introduced a product designed to print up to six times the normal capacity of type onto an 8½-by-11-inch page. This product, called MINI-PRINT, is intended for use with a dot matrix graphics printer. By directly driving the dot matrix pins, MINI-PRINT prints text in a supercompressed font.

The standard configuration of the MINI.EXE program prints six compressed pages of 66 lines each on an 8½-by-11-inch sheet of paper. MINI.EXE also can print a single page that is 192 characters wide and 198 lines long.

This extended column format is useful for printing program listings, spreadsheets, and database files. The tiny six-point type also is helpful when printing directory listings.

MINI-PRINT draws characters using a printer's graphics mode; each character is fitted inside a box that is 10 dots high and 5 dots wide. (Standard-sized characters are printed in boxes that are 36 dots high and 12 dots wide.) Lowercase MINI-PRINT characters with parts that descend below the line require two extra vertical dots. For every three passes of the print head, MINI-PRINT draws two lines of characters.

To print a file with MINI-PRINT, the user types the following:

d:>MINI <filename>

To pipe standard input to the MINI.EXE file, this command is used:

d:> DIR | MINI /P

The */P* instructs the program to use the standard DOS input file handle.

MINI.EXE is perhaps most useful when stored as a memory-resident program. It requires 85KB of memory. To install it and its print buffer permanently in memory, the user types:

d:>MINI /I

The resident MINI-PRINT reroutes all printer output to a six-page buffer. It

then waits for a full six pages of text before engaging the printer. The /U command forces the program to print out all text stored in the buffer and relinquish control. This does not return the program's memory to DOS, but the user can call the program again without taking additional memory.

Other commands allow for half- and full-page form feeds. The full-page feed acts as the standard form feed button on any printer, but maintains the critical line positioning required by MINI-PRINT. Exact page formatting is most important. A tiny error in the top margin can cause lines to be printed over perforations. Another disadvantage is that the user cannot adjust the blank space between lines. When text is printed in all capital letters, the lines almost touch and are difficult to read.

MINI-PRINT is highly sensitive to disturbance while printing. One page cannot be torn away while another page is being printed. Even this slight pressure causes text to fall out of alignment.

MINI-PRINT is supported by those printers that interpret the ESC 3 and ESC L control codes as they are interpreted by IBM printers. The ESC L command sets an IBM printer to a double density graphics mode that allows 120 dots per horizontal inch. ESC 3 sets IBM printers to space vertical lines in increments of 1/216 of an inch. Other printers that similarly interpret these commands include the Epson MX-80/100 with Graftrax, the Epson RX and FX series, Citizen, Roland, and Panasonic.

For this review, MINI-PRINT was tested on a PC/AT with 640KB of memory, a PC/XT with 512KB, and a PC with 640KB. These machines were attached to an IBM ProPrinter, an Epson MX-80, and a Panasonic KX-P1091. In each case, the program operated the printer without error. When running on the ProPrinter, MINI-PRINT used the 120 dot-per-inch mode, even though this printer offers a sharper 240 dot-per-inch mode.

The software is packaged in a thin plastic slipcover. The documentation is typeset in six-point characters on the back of the black and white diskette cover. The information is terse, but adequately describes the basics necessary to using the program.

The software package includes the MINI.EXE program, a backup copy called MINI.BAK, sample files, and a demonstration batch file. Also included is a utility that allows MINI-PRINT to print on both sides of a piece of paper.

—TOM SWAN

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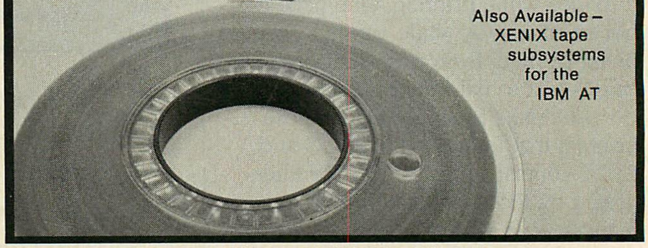

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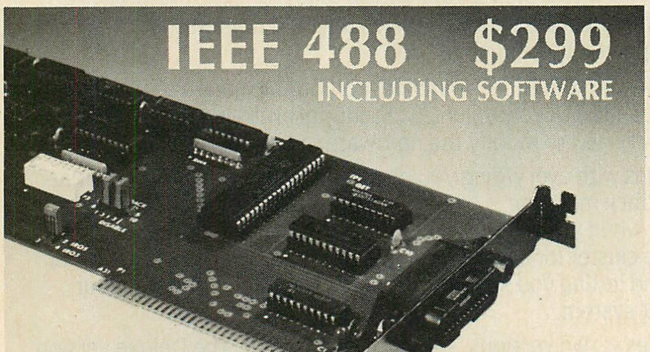

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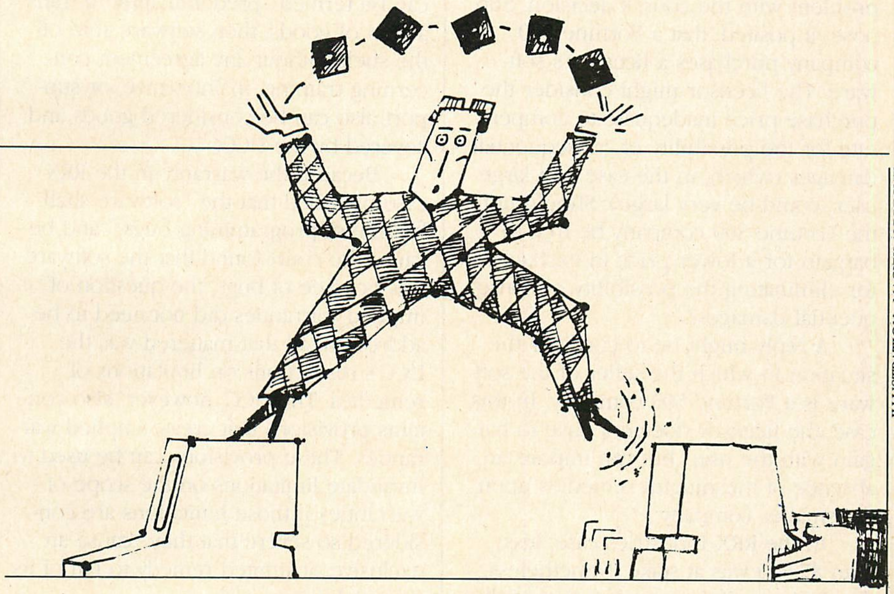
Software Goods or Services?

The sale of computer software can be considered a transaction of goods and is, therefore, covered by the UCC.



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One of the fundamental questions of computer law is whether software constitutes goods or services. This issue is significant because a set of laws known as the Uniform Commercial Code (UCC) creates rights and rules of conduct applicable to *goods* but not to *services*. (The UCC has been adopted by every state except Louisiana.)

Despite its importance, the question of software as goods or services has remained largely unanswered. Several courts have considered the issue of whether bundled software and hardware constitutes goods, and the conclusion has been that the bundle should be considered goods. These decisions, however, could have been based upon the comparative value of hardware and software.

In September 1985, however, a federal court of appeals was faced with the pure question of whether software alone constitutes goods or services. The case was RRX Industries, Inc. v. Lab-Con Inc. (772 F.2d 543, Ninth Cir. 1985).

The facts of the RRX case were quite straightforward. The user had entered into an agreement to license software and to acquire support and training from the licensor. The contract provided that the licensor:

> warrants that the software shall be free of programming 'bugs' for the term of the license, and that [the licensor] shall correct any such programming 'bugs' ...at no cost to the user. The liability of [the licensor] under this warranty, or under other warranty expressed or implied, shall be limited in amount [to the sum] that shall have actually been paid by the user...pursuant to... this Agreement.

Although this warranty is broader than most, the limitation of liability does not differ materially from the standard limitation of liability used in most shrink-wrapped license agreements.

The trial court concluded that the software never functioned as intended and that the licensor neither corrected the bugs (apparently because two key employees had left the company) nor provided sufficient training.

One of the most important issues of the case was whether the limitation of liability set forth in the contract was effective: if it was, the user was entitled only to be reimbursed the amount paid for the system ($40,866.66); if it was not, however, the user was entitled to recover not only the purchase price of the system, but also consequential damages (a total of $48,223.05).

Legal issues such as this often are decided on the basis of an analogy (see "Sales Tax and Software: Nothing is Simple," Legal Brief, January 1984, p. 196). For example, the sale of a piece of software can be compared to the sale of a phonograph record. In both cases, the product has little intrinsic value but contains encoded information that, when decoded by the appropriate mechanism, holds significant value for the purchaser. A phonograph record is, without question, a good, and its sale is governed by the UCC. Therefore, if the record analogy is accepted, a diskette containing software also should be considered a good, the sale of which is covered by the UCC.

On the other hand, consider a bookkeeper and a bookkeeping program. From the customer's point of view, it should not matter whether the books are kept by a human bookkeeper (clearly a transaction of services, not goods) or by a computer program. Presumably, the results are the same in both cases. If this analogy is accepted, a diskette containing bookkeeping software should be considered a service, even though the diskette itself can be considered a good.

The appeals court hearing the RRX Industries case concluded that the transaction between RRX and Lab-Con involved goods and that, as a result, the UCC of California applied. The court awarded the user consequential damages as well as the purchase price of the system. The remedies that the parties had written into the contract were rendered ineffective by the licensor's inability to live up to its end of the agreement and debug the software; the court "properly found the default of the seller so total and fundamental that its consequential damages limitation was expunged from the contract."

The court did not go so far as to conclude that software is, in all cases, to be considered goods. Its decision was based on a case-by-case analysis of whether a sale aspect or a service aspect predominated in each transaction. The analysis does suggest, how-

ever, that the software itself was viewed as goods, and that the issue was whether the contractual provisions for employee training, repair services, or future upgrades—which apparently were viewed as services—were important enough to outweigh the sale-of-software aspect of the transaction.

A dissenting opinion pointed out a problem with the court's decision. Suppose, it posited, that a Fortune 500 company purchases a licensor's software. The licensor might consider the purchase price inadequate to compensate for the possibility of consequential damages (which, in the case of a large user, could be very large). Should not the Fortune 500 company be free to bargain for a lower price in exchange for eliminating the possibility of consequential damages?

A reply might be to consider the situation in which the seller of the software is a Fortune 500 company. In this case, the licensor does not have to bargain with the user, but can impose an absence of meaningful remedies upon the smaller company.

In the RRX Industries case, less than $7,500 was at stake. Nonetheless, the decision of the case has potentially widespread implications. Although the transaction was termed a license agreement, the court held that the UCC applied. If a bargained limitation of remedies can be invalidated, the possibility of invalidation is even stronger in the case of shrink-wrapped licenses, which do not involve bargaining. If the sale of software that carries with it a promise of training, maintenance, and upgrades can be termed "predominantly" a transaction of goods, then software sold off the shelf without any agreement concerning training, maintenance, or support also can be considered goods and covered by the UCC.

Because the warranty in the RRX case provided that the "software shall be free of programming bugs," and because the court found that the software was not free of bugs, the question of implied warranties did not need to be addressed; all that mattered was the UCC's restrictions on limitations of remedies. The UCC, however, also contains provisions that create implied warranties. These provisions can be used to invalidate limitations on the scope of warranties if those limitations are considered so severe that they "cause an exclusive or limited remedy to fail of its essential purpose."

Additional UCC sections of interest make provisions for the following:

> If the court as a matter of law finds the contract or any clause of the contract to have been unconscionable at the time it was made the court may refuse to enforce the contract, or it may enforce the remainder of the contract without the unconscionable clause, or it may so limit the application of any unconscionable clause as to avoid any unconscionable result.
>
> Unless otherwise agreed, a seller dealing in goods of the kind that he regularly sells warrants that those goods shall be delivered free of the rightful claim of any third person by way of infringement or the like....
>
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>
> Modification (or exclusion) of warranties must be handled in a manner specified by the UCC.
>
> Every contract or duty...imposes an obligation of good faith in its performance or enforcement.

The decision of the RRX Industries case is only binding on federal courts of the ninth circuit. It is open to a future defendant in another jurisdiction to argue against the analysis of this case. Because the decision was made on a case-by-case basis, future defendants are left with the possibility of arguing that their cases are different from the RRX case. Software companies are probably instructing their lawyers to rethink their contracts at this very moment; hardware companies, too, might have cause for reflection.

Max Stul Oppenheimer, PC, is a partner in the law firm of Venable, Baetjer & Howard, located in Baltimore, Maryland.

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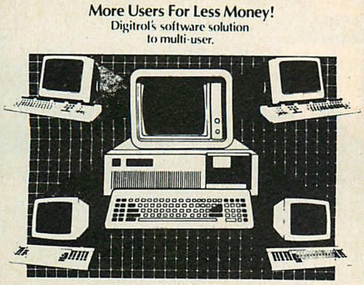

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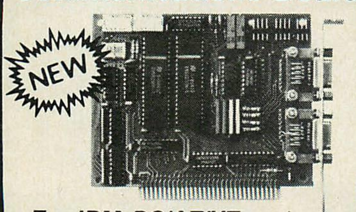

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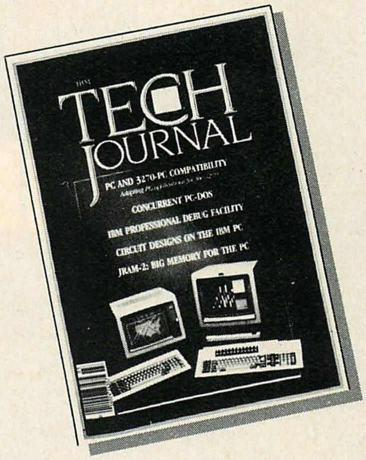

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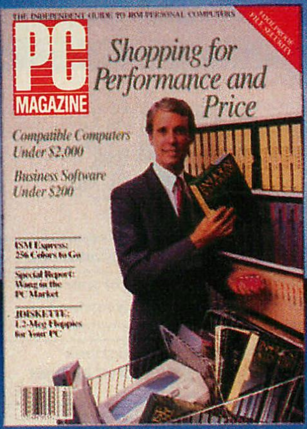

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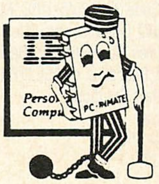

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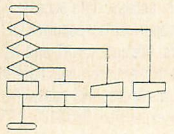

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Natural extension of DOS. Scroll back through screen output, edit text on full screen, mark blocks to printer or file, recall commands & directories, enter multiple commands, capture screens from application programs, create user profiles. Solid tech support. A real bargain at $49.95 VISA/MC

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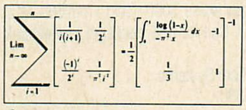

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TECH PC JOURNAL

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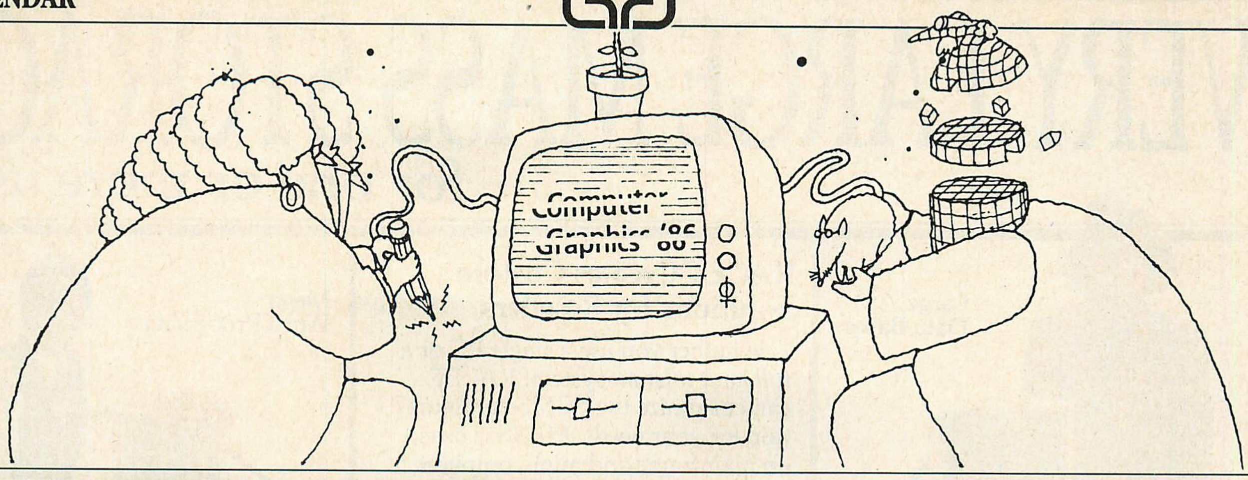

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MAY

May 1
Spring COMDEX
Atlanta, GA
Sponsor: The Interface Group
Contact: Linda Yogel, Registration Department, 300 First Avenue, Needham, MA 02194; 617/449-6600

May 11-15
International Small/Microcomputer Conference
Washington, DC
Sponsor: IEEE-CS
Contact: IEEE-CS, 1730 Massachusetts Avenue N.W., Washington, DC 20036-1903; 202/371-0101

May 11-15
Computer Graphics '86
Anaheim, CA
Contact: National Computer Graphics Association, 2722 Merrilee Drive, Suite 200, Fairfax, VA 22031; 703/698-9600

May 13-15
Computer Standards Conference 1986
San Francisco, CA
Sponsor: IEEE-CS
Contact: R. Poston, PEI, 68 Monmouth Road, Oakhurst, NJ 07755; 201/571-1071

May 28-30
18th Annual ACM SIGACT Symposium on Theory of Computing
Berkeley, CA
Sponsor: Association for Computing Machinery
Contact: Eugene L. Lawler, Computer Science Division, Evans Hall, University of California at Berkeley, Berkeley, CA 94720; 415/642-4019

JUNE

June 3-5
13th International Symposium on Computer Architecture
Tokyo, Japan
Sponsor: Information Processing Society of Japan
Contact: Shunichi Uchida, ICOT, Mita Kokusai Building 21F, 4-28 Mita 1-Chome, Minato-ku, Tokyo 108, Japan

June 4-6
National Educational Computing Conference
San Diego, CA
Sponsor: ACM, IEEE, SCS
Contact: Susan M. Zgliczynski, University of San Diego, School of Education, Alcala Park, San Diego, CA 92110

June 12-13
Distributed Information Systems
Gaithersburg, MD
Sponsor: ACM and the United States Department of Commerce
Contact: National Bureau of Standards;Gaithersburg, MD 20899; 301/964-6508

June 16-19
National Computer Conference
Las Vegas, NV
Sponsor: AFIPS, ACM, IEEE-CS, DPMA, and SCS
Contact: AFIPS, 1899 Preston White Drive, Reston, VA 22091; 703/620-8900

June 22-25
23rd Design Automation Conference
Las Vegas, NV
Sponsor: ACM SIGDA and IEEE-CS
Contact: J. D. Nash, Raytheon Company, Bedford, MA 01730; 617/274-7100, ext. 4758

June 22-26
Computer Vision and Pattern Recognition
Miami Beach, FL
Contact: Computer Vision and Pattern Recognition, 1730 Massachusetts Avenue NW, Washington, DC 20036-1903; 202/371-0101

June 22-August 1
National Computer Camps
CT, OH, GA
Contact: National Computer Camps, Box 585-CA, Orange, CT 06477; 203/795-9667

June 23-27
Compiler Construction
Palo Alto, CA
Sponsor: Association for Computing Machinery
Contact: ACM 11 W. 42nd Street, New York NY 10036; 212/575-1520

JULY

July 7-11
APL '86
Manchester, England
Sponsor: British Computer Society and ACM SIGAPL
Contact: BISL Conference Department, The British Computer Society, 13 Mansfield Street, London W1M 0BP, England

July 9-11
PC EXPO
New York, NY
Contact: 333 Sylvan Avenue, Englewood Cliffs, NJ 07632; 201/569-8542

July 21-25
European Conference on Artificial Intelligence
Brighton, U.K.
Sponsor: The Society for the Study of Artificial Intelligence and Simulation Behavior
Contact: Benedict du Boulay, ECAI, The University of Sussex, Cognitive Studies Programme, Brighton BN1 9QN, U.K.

July 21-26
Third International Conference on Logic Programming
London, England
Contact: Doug DeGroot, IBM Research, P.O. Box 218, Yorktown Heights, NY 10598

AUGUST

August 5-7
ACM SIGCOMM Futures in Communications Conference
Stowe, VT
Sponsor: ACM SIGCOMM
Contact: Walter Kosinsky, Norwich University, Northfield, VT 05663; 802/485-5011, ext. 237

August 18-22
ACM SIGGRAPH '86
Dallas, TX
Contact: Ellen Gore, ISSCO, 10505 Sorrento Valley Road, San Diego, CA 92121; 619/452-0170

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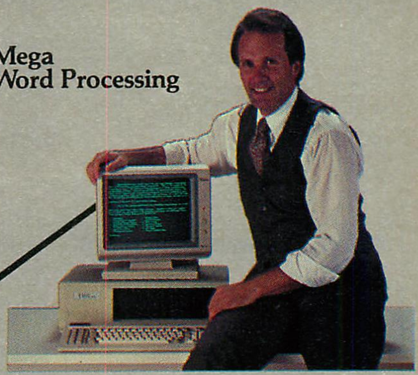

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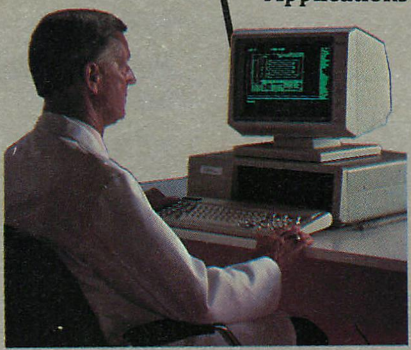

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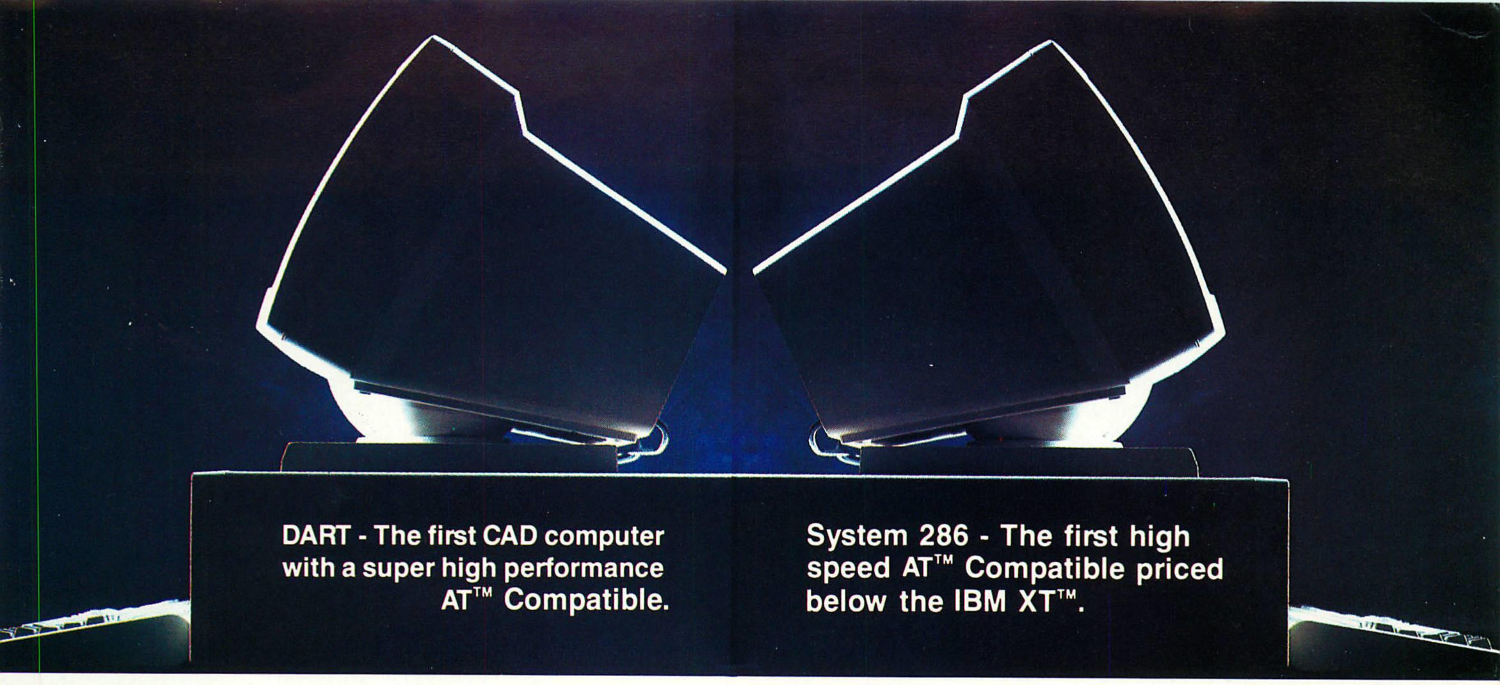

WE DON'T THINK YOUR PERFORMANCE SHOULD BE LIMITED BY THE 'STANDARD'

At ALR we don't think your performance should be limited by the 'Standard'. So preoccupied are today's computer makers with meeting the 'Standard', they seem to have overlooked the opportunity to do something much more worthwhile.

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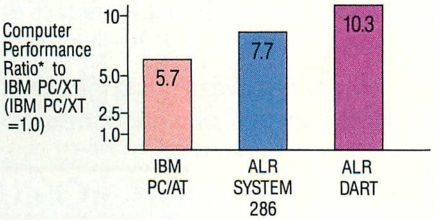
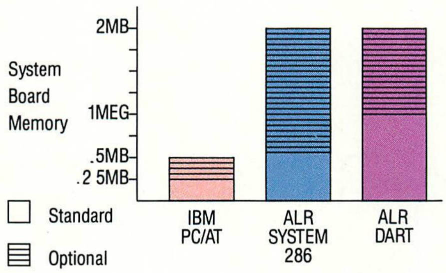


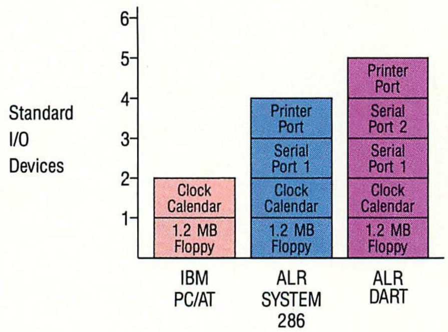
*Based on the Norton Utility SI-System Information Command.

Explore the opportunity of the System 286 - The first high speed AT below the price of an IBM XT™. The low cost of this system did not reduce the performance, with the cpu speed of 8 MHz and co-processor speed of 5 MHz. This System 286 is ready to calculate spread sheets and sort data base in a flash!

The concept of having enough memory is misleading. It seems yesterday's 64K of memory was enough. Today, computers require at least 512K in order to run popular programs such as Symphony™ or Framework.™ The result? ALR System 286 and DART system both have four times the memory capability built into its 'motherboard' so you don't have to pay for it tomorrow.



Option I/O device? That usually implies you need it and it costs more. ALR believes a computer needs to interface with at least a printer and in most cases modems, plotters and other computers, so we design our systems to include more standard I/O.



High performance and more features usually results in a more expensive system. However, the ALR System 286 and DART system does not match the 'Standard' price and this is one category we're glad to be considered 'sub-standard'.

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You'll see the program on your remote terminal screen as if you were seated at the host PC.

While Remote itself becomes transparent in use, it offers some very tangible benefits:

- You don't need a second PC to do the job of two. Almost any terminal or terminal emulator will do. The only software you need is the software in your host PC.
- Each of several different users can call in from anywhere in the world and use the host PC and software. Remote includes a sophisticated electronic mail system with encrypted messages and individual password protection.
- You can transfer files to and from the host computer, using the Crosstalk or XMODEM protocol.
- Programmers and software vendors can use Remote to debug a client's software by phone, without leaving their own offices.

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